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TM4-275-MI

JOHN F. KENNEDY
SPACE CENTER

TECHNICAL MANUAL

APOLLO/SATURN

C00. 00. 19. 3

OPERATIONS AND MAINTENANCE

CATHODIC PROTECTION
OF COMMUNICATION CABLES

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14 September 1970

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FOREWORD

AUTHORITY

This manual was prepared for the Canaveral District of the United States Army Corps of Engineers by The Ralph M. Parsons Company under Contract Number DACA18-70C-9031.

LIST OF RELATED MANUALS

TM NUMBER	TITLE
None	

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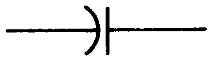
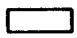
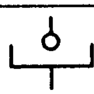
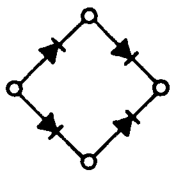
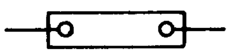
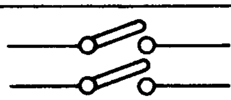
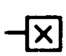
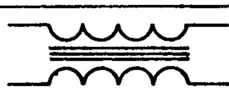
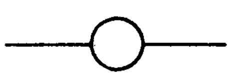
LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
Amp	Amperes
CD & SC	Communications, Distribution and Switching Center
CIF	Central Instrumentation Facility
CM	Centimeter
EP	Explosion Proof
F	Fahrenheit
FCA	Frequency Control Analysis
FEC	Federal Electric Corporation
GR	Grain
GSA	Government Service Agency
HTHW	High Temperature Hot Water Line
KSC	Kennedy Space Center
LUT	Launch Umbilical Tower
ML	Milliliter
MV	Millivolt
NIC	Not in Contract
POL	Paint and Oil Locker
PSI	Pounds per Square Inch
R	Rectifier
T & B Sta	Test and Bond Station
VAB	Vehicle Assembly Building
VAC	Volts Alternating Current
VDC	Volts Direct Current

LIST OF DESIGNATORS

C1	Capacitor
CB1	Circuit Breaker
FC1	Filter Choke
FU1	Fuse
LA1 & LA2	Lightning Arrestors
M1	Meter
R1	Resistor, Fixed
R2	Resistor, Adjustable
RECT1	Rectifier
SH1 & SH2	Shunt, Meter
SW1 & SW2	Switch, Toggle
T1	Transformer

SYMBOL	DESCRIPTION
	Capacitor
	Circuit Breaker
	Cabinet, Communication
————————	Cathodic Protection Cable, Direct Burial
---- ----	Communications, Direct Burial Cable
——— ———	Communications, Duct Run
————————	Component Designator RSPL Find Number
--------	Conduit Underground Below Road & Sidewalk
	Filter Choke
	Fuse
	Insulating Joint
	Lightning Arrestor
■	Manhole, Communication
□	Manhole, Electrical

SYMBOL	DESCRIPTION
●	Marker
	Panel, Power or Lighting 120/208V ac
	Rectifier, dc
	Rectifier, Full Bridge
	Resistor, Adjustable
	Resistor, Fixed
	Shunt, Meter
	Site Location for Cathodic Protection System
	Joint, Splice
	Switch, Fused Disconnect, 30A-120V ac-2W-SN Fused 20 amp
	Switch, Toggle
	Test and Bond Station
▲	Transformer
	Transformer
	Voltammeter

SCHEDULE OF SITES

SITE NO.	SYSTEM LOCATION (AT OR NEAR BUILDING OR INTERSECTION)	SIZE		RECTIFIER ENCLOSURE, MOUNTING AND TYPE	FIGURE REFERENCE	
		VOLTS	AMPS		LOCATOR	SCHEMATIC
1	HIGH RESOLN TRKG STA TRAILER COMPLEX	84	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-2	FIG. 2-1 CKT NO. 1
2	FEC STORAGE BLDG J6-2377 & TEST & BOND STA #8 & #9	30	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-4	FIG. 2-1 CKT NO. 1
3	STORAGE BUILDING (LUT AREA)	9	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-3	FIG. 2-1 CKT.NO. 1
4	SEWAGE TREATMENT PLANT BLDG K6-792	24	9	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-5	FIG, 2-1 CKT NO. 1
5	VAB RPTR BLDG K6-1193 & TEST & BOND STA #15	60	18	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-6	FIG. 2-1 CKT NO. 2
6	COE BLDG K6-1146 & TEST & BOND STA #14	24	18	WTHPRF, PEDESTAL MDT & AIR COOLED	FIG. 1-7	FIG. 2-1 CKT NO. 1
7	TANKER OVERHAUL FACILITY BLDG K6-1446	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-9	FIG. 2-1 CKT NO. 1
8	VAB INSTRUMENTATION BLDG K7-1557	24	9	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-10	FIG. 2-1 CKT NO. 1
9	COMMUNICATION BLDG (PRESS SITE TRLR AREA)	36	18	STD WALL MTD (OUT) & AIR COOLED	FIG. 1-8	FIG. 2-1 CKT NO. 1
10	HIGH PRESSURE GAS STORAGE BLDG K7-853	30	28	EXPLOSION PRF, BASE MTD & OIL IMMERSED	FIG. 1-11	FIG. 2-1 CKT NO. 2
11	UNIVERSAL CAMERA SITE UCS NO. 18 & TEST & BOND STA #16	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-12	FIG. 2-1 CKT NO. 1
12	SWARTZ RD NEAR KENNEDY PKWY & TEST & BOND STATIONS #17 & #18	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-14	FIG. 2-1 CKT NO. 2
13	WEATHER TOWER NO. 6 EQPT BLDG L6-75	24	9	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-14	FIG. 2-1 CKT NO. 1
14	FREQ CONT ANAL BLDG L5-683 (NEAR FCA RD)	9	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-15	FIG. 2-1 CKT NO. 1
15	NOT USED					
16	UNIFIED S BAND POWER BUILDING M5-1444	18	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-16	FIG. 2-1 CKT NO. 1
17	VISITORS INFO CENTER BLDG M6-409	18	18	STD WALL MTD (OUT) & AIR COOLED	FIG. 1-17	FIG. 2-1 CKT NO. 1
18	COMM. DIST & SW CEN (CDSC) BLDG M6-138	72	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-18	FIG. 2-1 CKT NO. 1
19	CD AND SC BUILDING M6-138	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-19	FIG. 2-1 CKT NO. 1
20	EMER GEN BLDG (NEAR CIF ANT. OPS BLDG M6-342)	30	28	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-20	FIG. 2-1 CKT NO. 1
21	WEATHER TOWER NO. 1 EQPT BLDG (NEAR TST STD RD IN TWA RESC AREA)	36	18	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-21	FIG. 2-1 CKT NO. 1
22	FCA VAN SITE (NEAR STATIC TEST RD)	24	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-22	FIG. 2-1 CKT NO. 1
23	BANANA RIVER REPEATER BLDG M7-351	18	18	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-23	FIG. 2-1 CKT NO. 1
24	INTERSECTION OF NASA PKWY & E AVE & TEST & BOND STA #22	96	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-24	FIG. 2-1 CKT NO. 1
25	CENTRAL INSTM FACILITY (CIF) BLDG M6-342	48	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-25	FIG. 2-1 CKT NO. 1
26	ELECTROMAG LAB M6-336 (FRMRLY COE RESID)	48	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-26	FIG. 2-1 CKT NO. 1
27	KSC HQ BLDG M6-399 EQPT ROOM R1634	72	9	STD WALL MTD (INSIDE) & AIR COOLED	FIG. 1-27	FIG. 2-1 CKT NO. 1
28	KSC AUD BLDG M7-351 & TEST & BOND STATION #23	30	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-28	FIG. 2-1 CKT NO. 1
29	NASA NEWS CENTER BLDG M7-657	18	18	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-29	FIG. 2-1 CKT NO. 1
30	GAS STA AT 3RD ST & TEST & BOND STA #28 & #29	72	9	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-30	FIG. 2-1 CKT NO. 1
31	MN CAFETERIA M6-493 & TEST & BOND STA #22	36	18	STD WALL MTD (INSIDE) & AIR COOLED	FIG. 1-31	FIG. 2-1 CKT NO. 2
32	PNT & OIL STOR (POL) M6-584 & TEST & BOND STA #27	36	9	WHTPRF, WALL MTD & AIR COOLED	FIG. 1-32	FIG. 2-1 CKT NO. 1
33	INTERSECTION OF 5TH ST & KENNEDY PKWY	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-33	FIG. 2-1 CKT NO. 1
34	AUTOMN MAINT & SVCE M6-688 (GSA BLDG)	60	18	WTHPRF, PEDESTAL MTD & AIR COOLED	FIG. 1-34	FIG. 2-1 CKT NO. 1
35	RADAR BORESITE RANGE CONTROL M7-867	24	18	WTHPRF, WALL MTD (OUT) & AIR COOLED	FIG. 1-35	FIG. 2-1 CKT NO. 1
36	ORDNANCE LAB NO. 2 BLDG M7-1417	18	18	EXPLOSION PRF, BASE MTD & OIL IMMERSED	FIG. 1-36	FIG. 2-1 CKT NO. 1

SECTION I
DESCRIPTION

1.1 GENERAL

This manual contains Operation and Maintenance Instructions with Provisioning Lists for the Cathodic Protection System for Communication Cables, KSC. The individual segments comprising the overall system are installed at Sites 1 through 40 (Site No. 15 excepted), John F. Kennedy Space Center, Merritt Island, Florida. A schedule of sites is provided in the front matter of this manual for ready reference to site locations and other pertinent data. (See Figure 1-1 for general location of the system and Figures 1-2 through 1-50 for segmented site and test and bond station locations.)

1.2 CATHODIC PROTECTION SYSTEM FOR COMMUNICATION CABLES

The Cathodic Protection System identified above is designed to prevent or arrest corrosion of communication cables buried in soil or submerged in water by impressing sufficient direct current from the rectifier through the anodes to the cable. This process neutralizes or counteracts current flowing from the cable into the soil or water; thus, preventing or arresting corrosion of the cable sheath material. The thirty-nine segments of the overall system (refer to the Schedule of Sites) are identical except as follows: size of rectifiers vary affecting operating capacity; rectifier enclosures are either wall mounted, pedestal mounted or base mounted (oil immersed and explosion proof); and the number of anodes per site vary to provide adequate protection of the cable runs. The following components are common to each segment of the overall system; fused disconnect switch, rectifier unit and an anode bed. Test and Bond Stations are provided to balance the system and these stations are listed in the Schedule of Sites and are illustrated on equipment locators in Section I, as applicable. (Refer to Table 1-1 Leading Particulars of major system components.)

1.2.1 **RECTIFIER UNIT.** The rectifier unit at each site provides the low voltage, direct current potential that is impressed on the cable sheath. Each unit is a selenium type, full wave bridge rectifier; either air cooled or oil immersed and explosion proof as shown on the Schedule of Sites. Power to the rectifiers is supplied from a 115 vac, single phase, 60 cycle source through a fused disconnect switch. Each rectifier is equipped with the following components; an ac lightning arrestor, circuit breaker and transformer on the primary side; and a filter choke, fuse, capacitor, unimeter (voltmeter and ammeter) complete with selector switch, dc lightning arrestor and a rheostat on the secondary side. Rectifiers at Sites 5, 10, 12, and 31 only are equipped with a rheostat to provide a means of adjusting or balancing the output current between two anode beds. (Refer to Table 1-1 for Leading Particulars of the rectifier units.)

1.2.2 ANODE BED. The anode beds are preselected to provide full protection of the cable between sites and each bed contains a predetermined number of anodes as shown on Figures 1-2 through 1-40. The bed consists of a predetermined number of anodes, connected by an insulated header cable leading from the positive terminal of the rectifier. Concrete markers are installed over the first and last anode in each ground bed except where anodes are submerged in water. In this case, a marker is installed over the cable, three feet from the water's edge to signify a buried anode string. Each anode is a 2 x 60 inch unit with 5 feet of 8/7 strand cable lead with a Durcon 164 encapsulation of cable to anode connection. (See Figures 1-2 through 1-40 for the number of anodes installed at each site.)

1.2.3 TEST AND BOND STATIONS. Test and Bond Stations provide above grade connections to cable sheath or other buried protected structure for balancing the overall cathodic protection system as each segment or site is dependent on the adjacent one to maintain an adjusted and balanced system. Also, the test and bond station provide a means of testing underground metallic structures or utilities that are in proximity to the cathodic protection system to determine if the system is causing corrosion of these utilities. If so, then a bonding jumper must be provided between the structure or utility and the cable sheath. The bond and test station consists of a NEMA 4 'J' box mounted to a 4 x 4 x 5 foot long wood post. Test cables from the cable sheath being protected or other protected structures are terminated in the station terminal box. At locations where only one communication cable is present, two black wires are installed; and at locations where only one structure (sewer or water line) is present, two white wires are installed. All test leads are identified by 1-inch diameter lead tags at the terminal block. (See Figures 1-4, 1-6, 1-7, 1-12, 1-13, 1-24, 1-28, 1-30 through 1-32, 1-37 and 1-41 through 1-50 for Test and Bond Station locations.)

1.3 LEADING PARTICULARS

Leading particulars of major system components are contained in Table 1-1.

Table 1-1. Leading Particulars (Sheet 1 of 2)

RECTIFIERS	
Type	Air Cooled
Power Rating:	
Input	120 vac, single phase, 60 cycle
Output	9 volt, 9 amp; 18 volt, 18 amp; 24 volt, 9 amp; 24 volt, 18 amp; 30 volt, 9 amp; 30 volt, 18 amp; 30 volt, 28 amp; 36 volt, 9 amp; 36 volt, 18 amp; 48 volt, 9 amp; 48 volt, 18 amp; 60 volt, 18 amp 72 volt, 9 amp; 72 volt, 18 amp; 84 volt, 9 amp; 84 volt, 18 amp; 96 volt, 18 amp
Fuse	Refer to Section IX
Dimensions (Approximate):	
Length:	
Top	23 1/4 inches
Base	16 3/4 inches
Width	15 inches
Height:	
Base to Top	25 inches
Overall	29 3/4 inches
Type	Oil Immersed-Explosion Proof
Power Rating:	
Input	120 vac, single phase, 60 cycle
Output	18 volt, 18 amp; 30 volt, 28 amp
Fuse	Refer to Section IX
Dimensions:	
Length	28 inches
Width	14 inches
Height	30 inches
Type Oil	Transformer Oil less Inhibitor (Approved Grade)
Capacity	39 gallons
ANODE	
Physical Properties:	
Tensile Strength (1/2" Dia. Bar)	15, 000 psi
Compressive Strength	100, 000 psi
Hardness, Brinell	520

Table 1-1. Leading Particulars (Sheet 2 of 2)

ANODE (Continued)	
Physical Properties: (Continued)	
Density	7.0 gr/ml
Melting Point	2,300^{o}F
Specific Resistance	72 micro-ohms/cm^{3} 20^{o}C
Coefficient of Expansion	7.33 x 10-6 32^{o} - 212^{o}F
Nominal Chemical Analysis - Durichlor 51:	
Silicon	14.40 percent
Carbon	1.00 percent
Manganese	0.70 percent
Chromium	4.25 percent
Iron	Remainder
Size	2 inch dia x 60 inches long
Type Cable	HMPE 8/7 Strand with Durcon 164 Encapsulation of Cable to Anode
Cable Length	5 feet
TEST AND BOND STATIONS	
Cable Sheath Test Leads:	
Stranded Cable	Type TW No. 8 with Black Insulation
Solid Cable	Type TW No. 12 with Black Insulation
Adjacent Structure Test Leads:	
Stranded Cable	Type TW No. 8 with White Insulation
Solid Cable	Type TW No. 12 with White Insulation

FOLDOUT FRAME 1

FOLDOUT FRAME 2

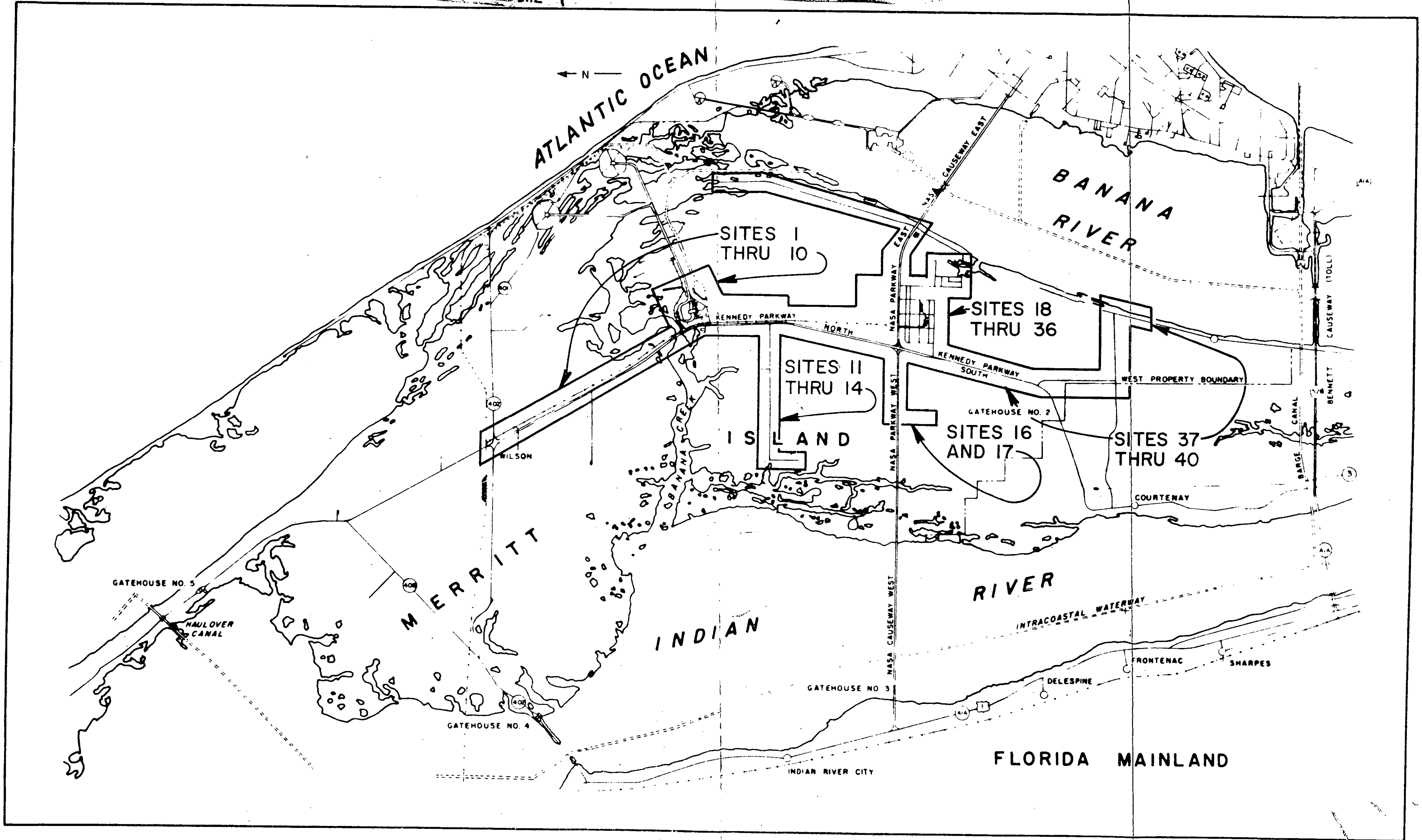


Figure 1-1. Cathodic Protection Systems Location Diagram (Sheet 1 of 4)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

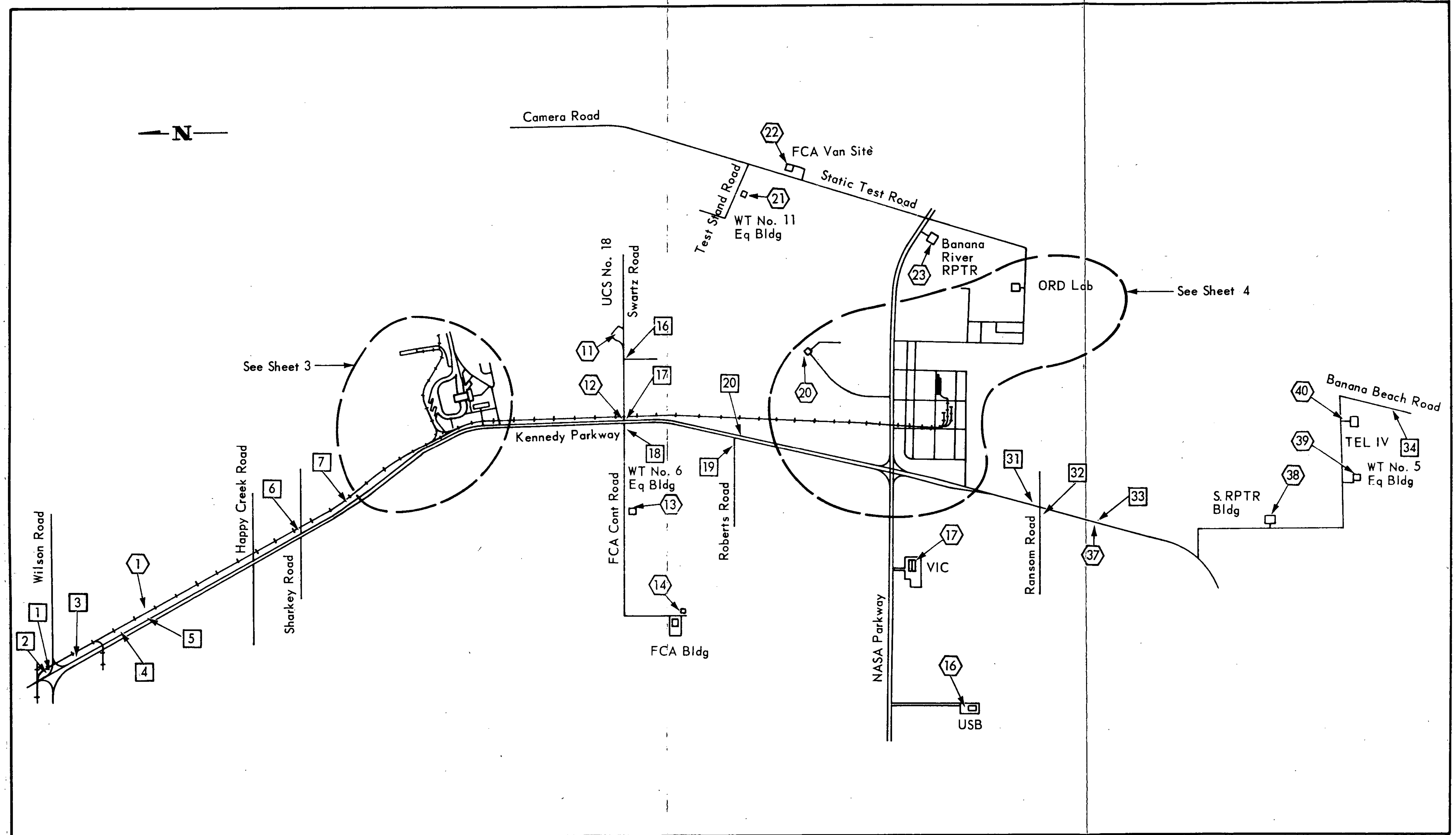


Figure 1-1. Cathodic Protection Systems Location Diagram (Sheet 2 of 4)

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FOLDOUT FRAME 2

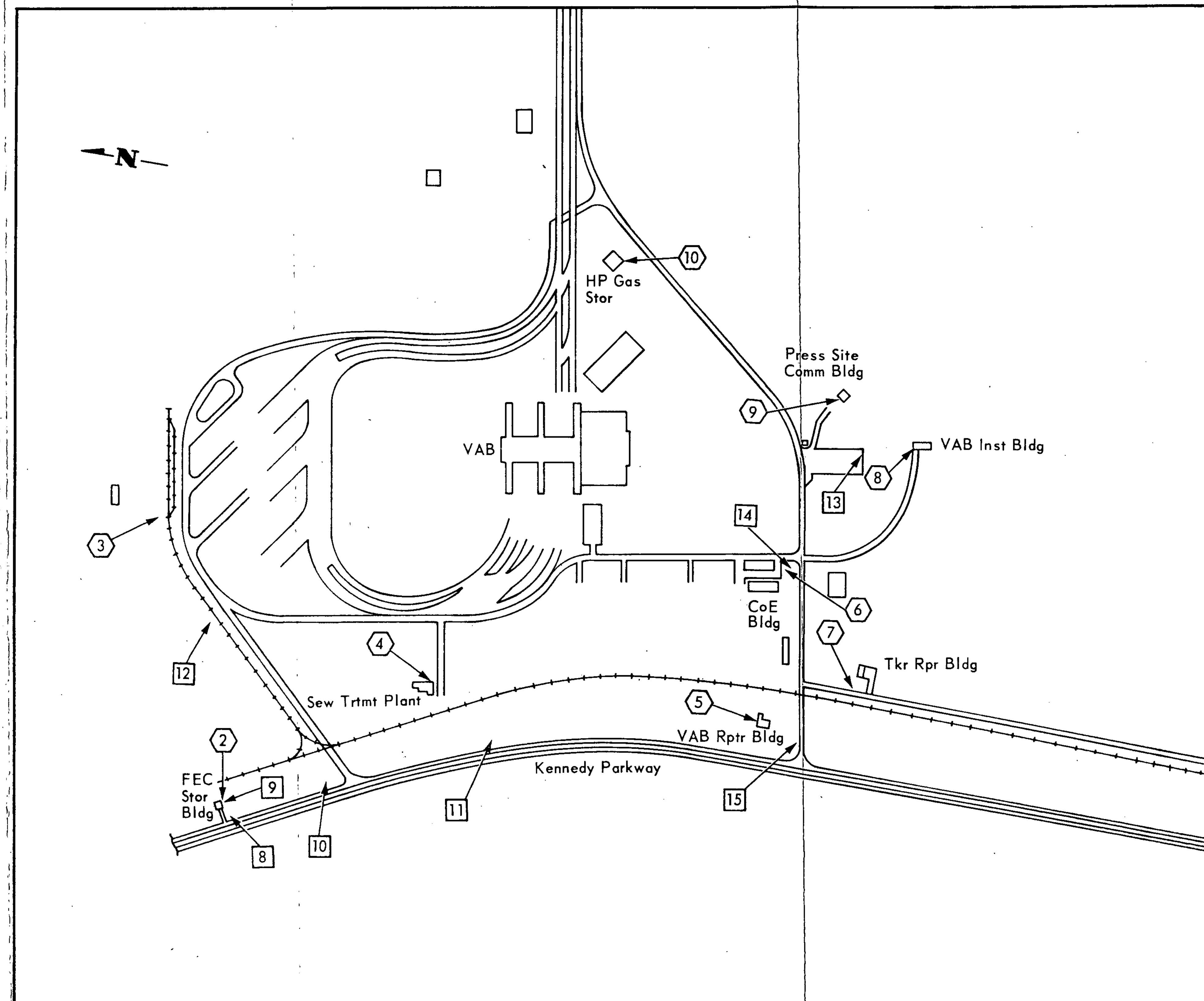


Figure 1-1. Cathodic Protection Systems Location Diagram (Sheet 3 of 4)

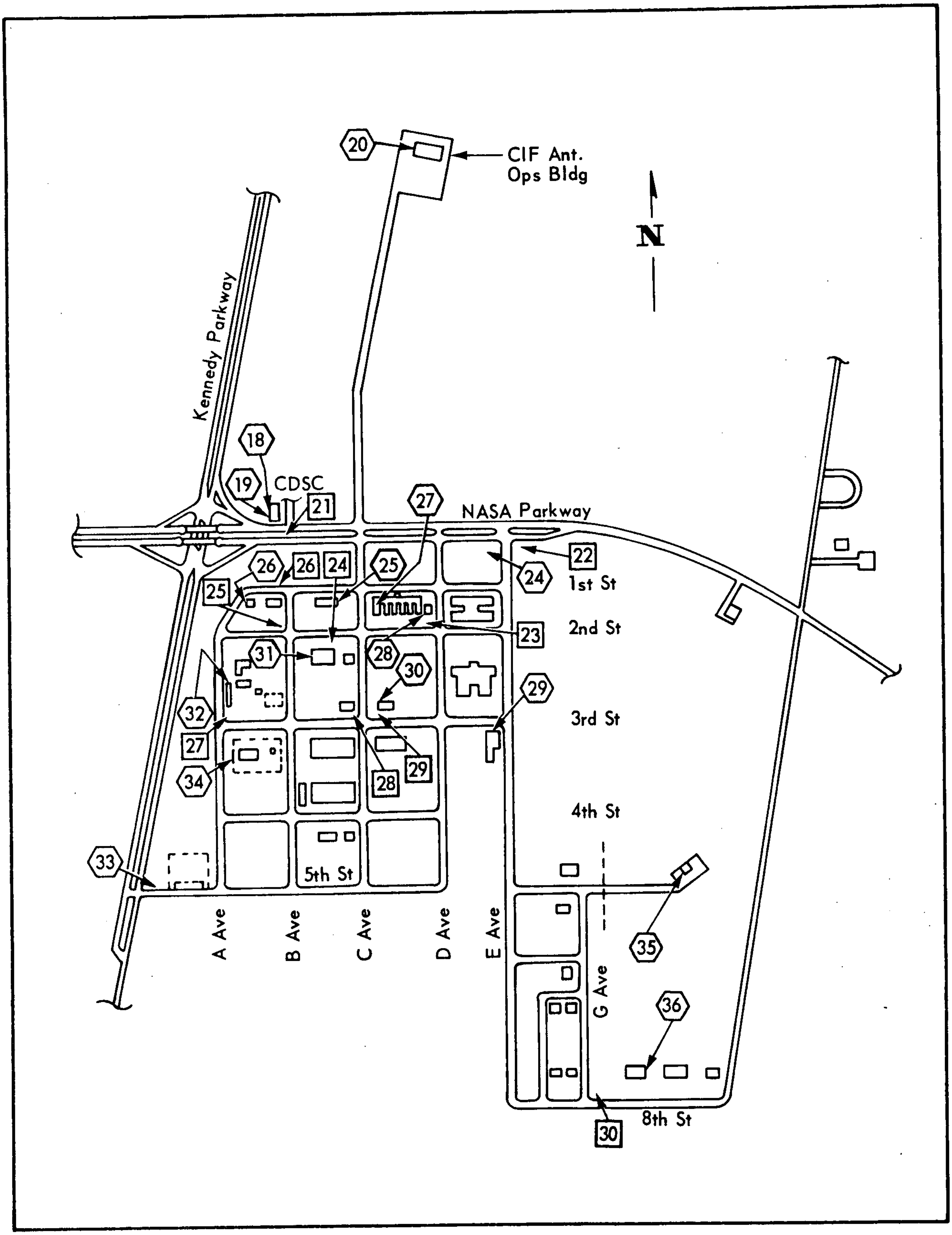


Figure 1-1. Cathodic Protection Systems Location Diagram (Sheet 4 of 4)

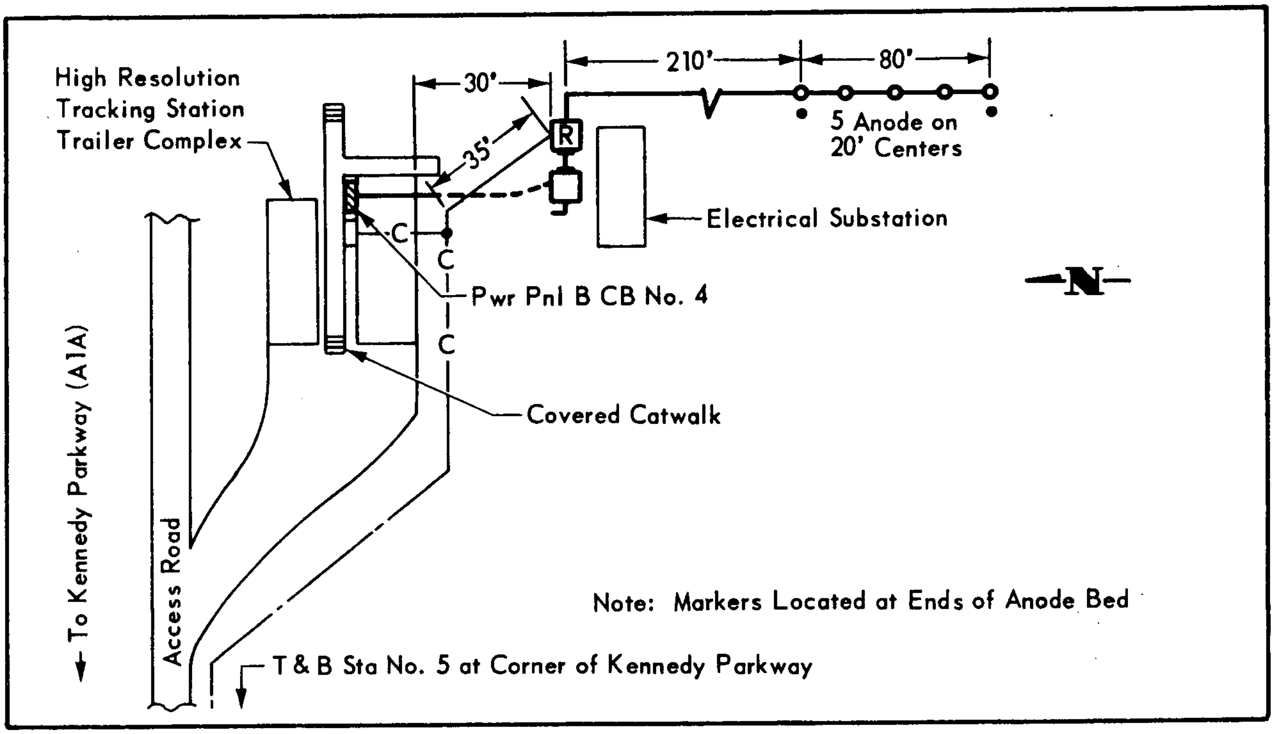


Figure 1-2. Site No. 1 Equipment Locator

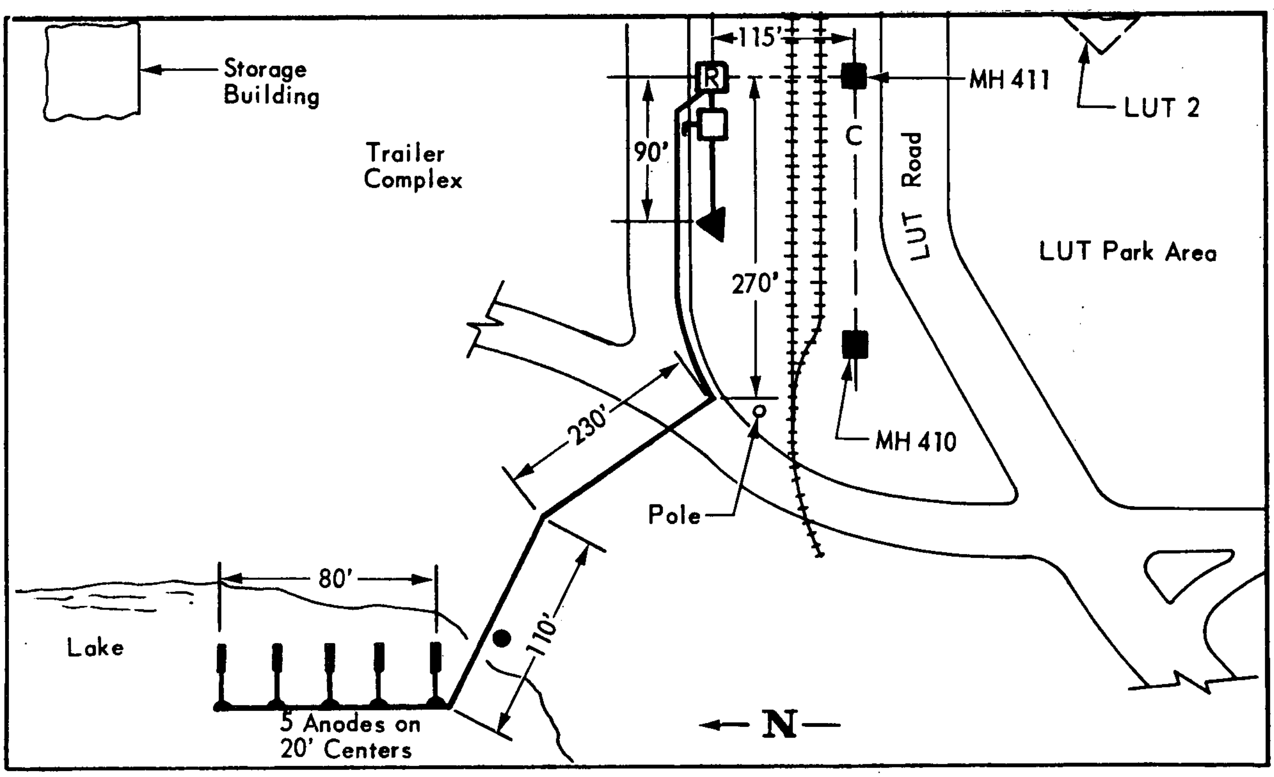


Figure 1-3. Site No. 3 Equipment Locator

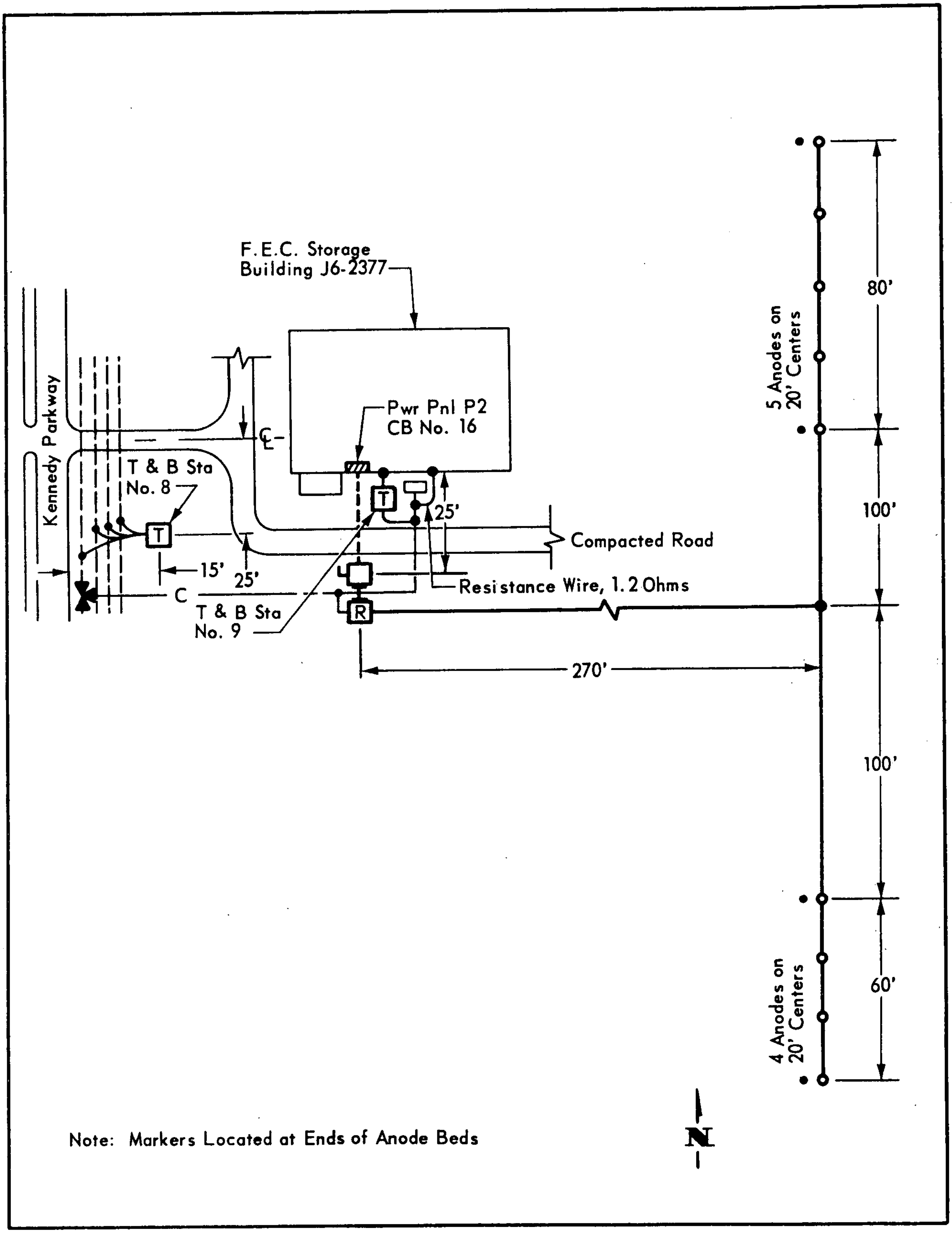


Figure 1-4. Site No. 2 and Test and Bond Station Nos. 8 and 9 Equipment Locator

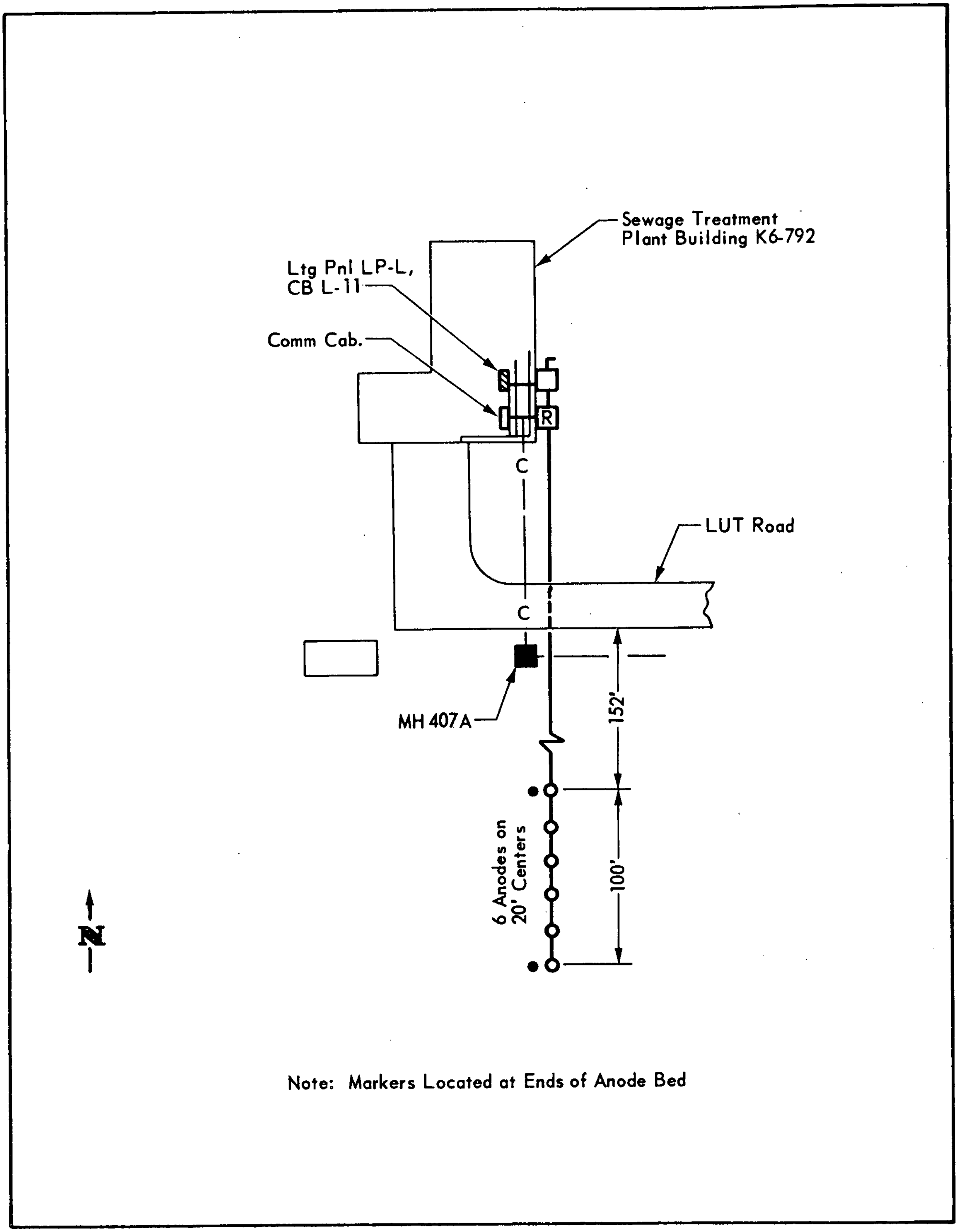


Figure 1-5. Site No. 4 Equipment Locator

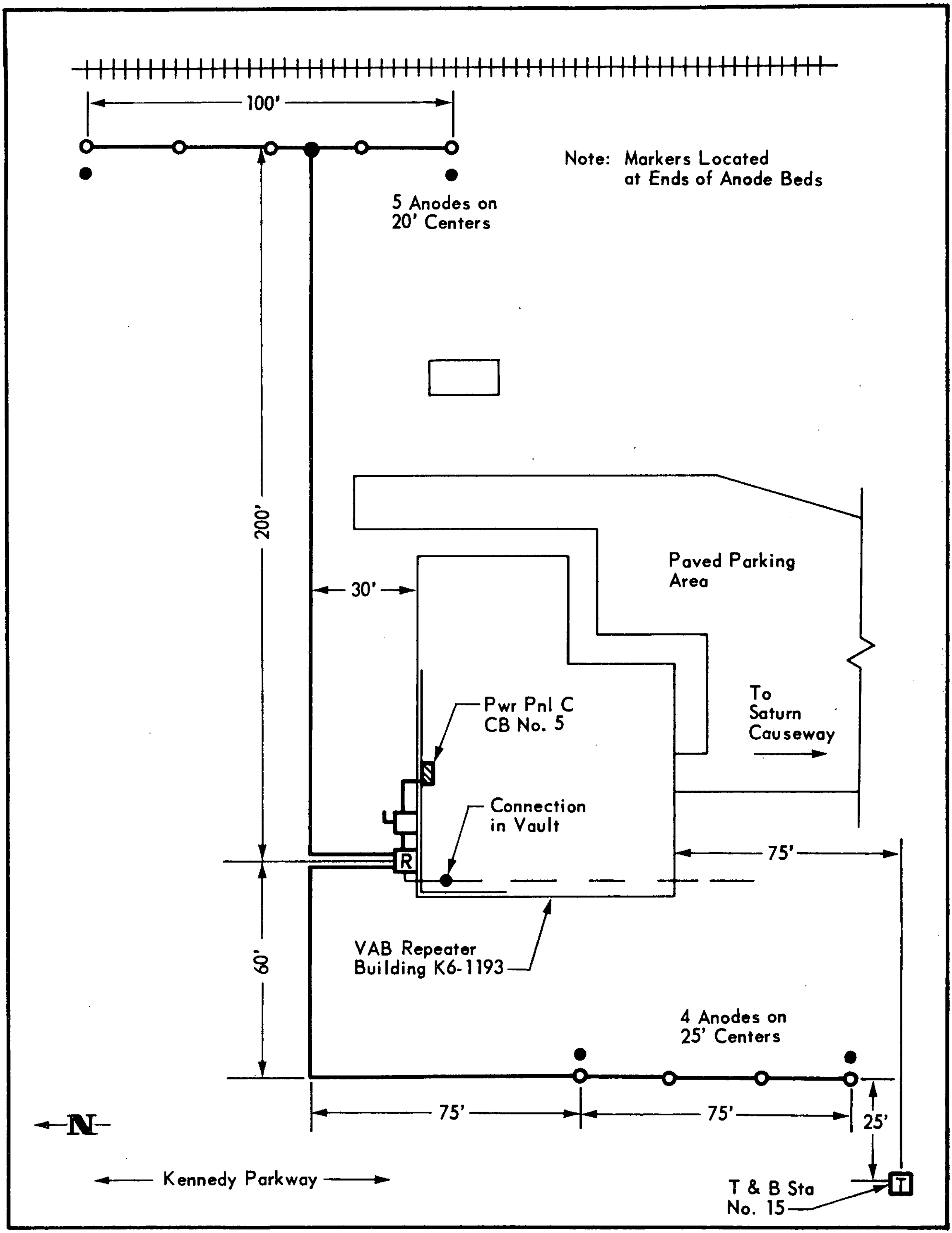


Figure 1-6. Site No. 5 and Test and Bond Station No. 15
Equipment Locator

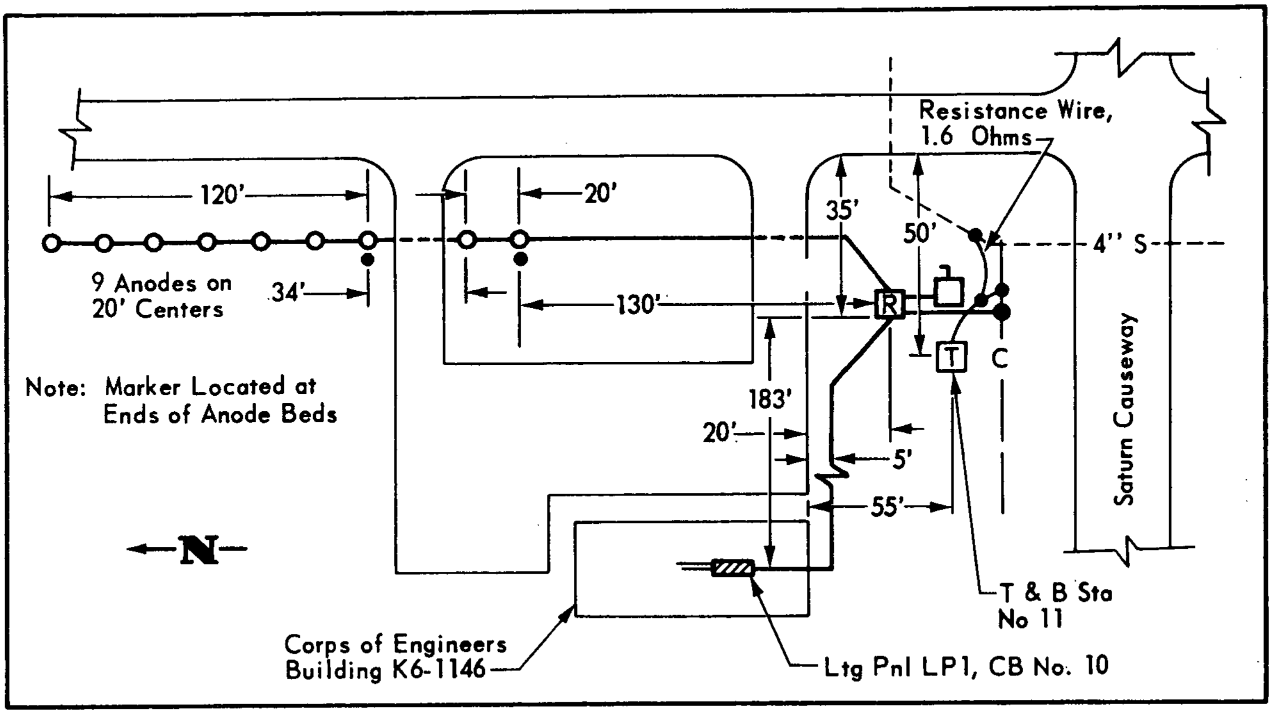


Figure 1-7. Site No. 6 and Test and Bond Station No. 14
Equipment Locator

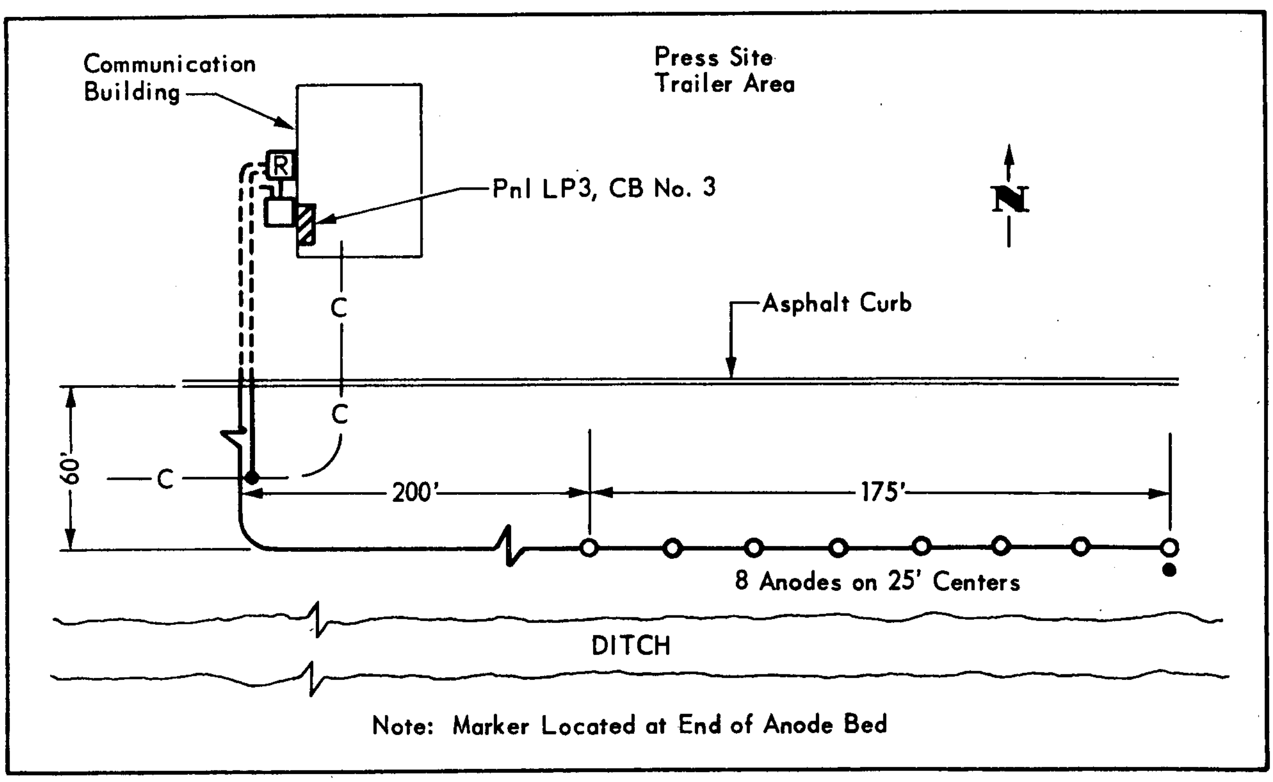


Figure 1-8. Site No. 9 Equipment Locator

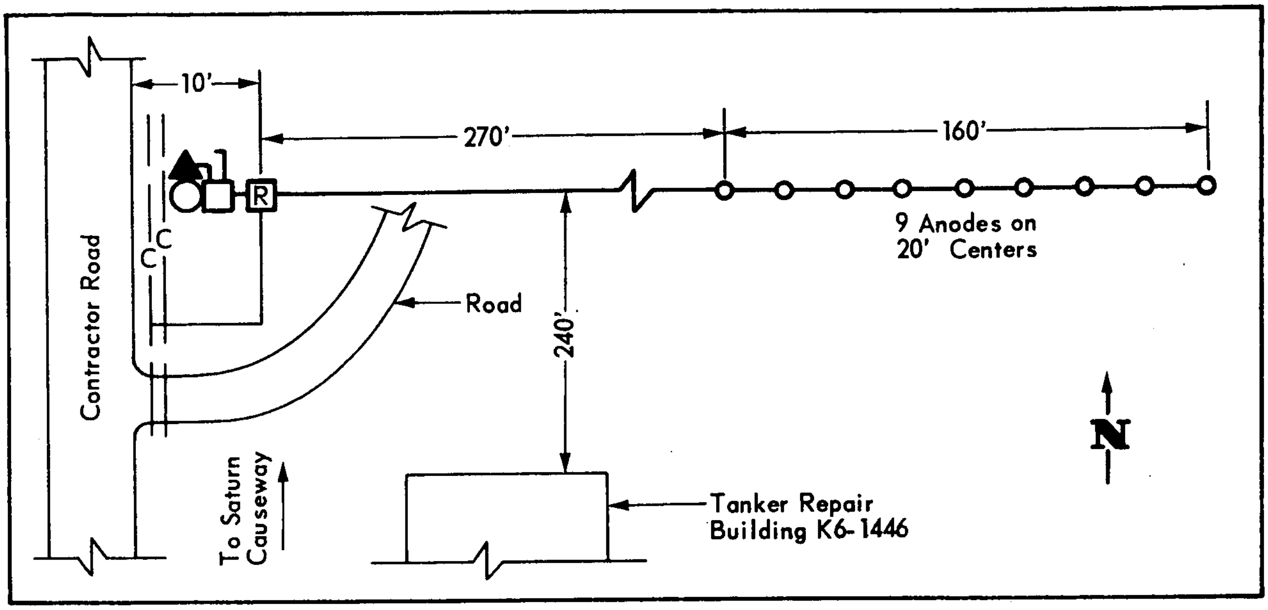


Figure 1-9. Site No. 7 Equipment Locator

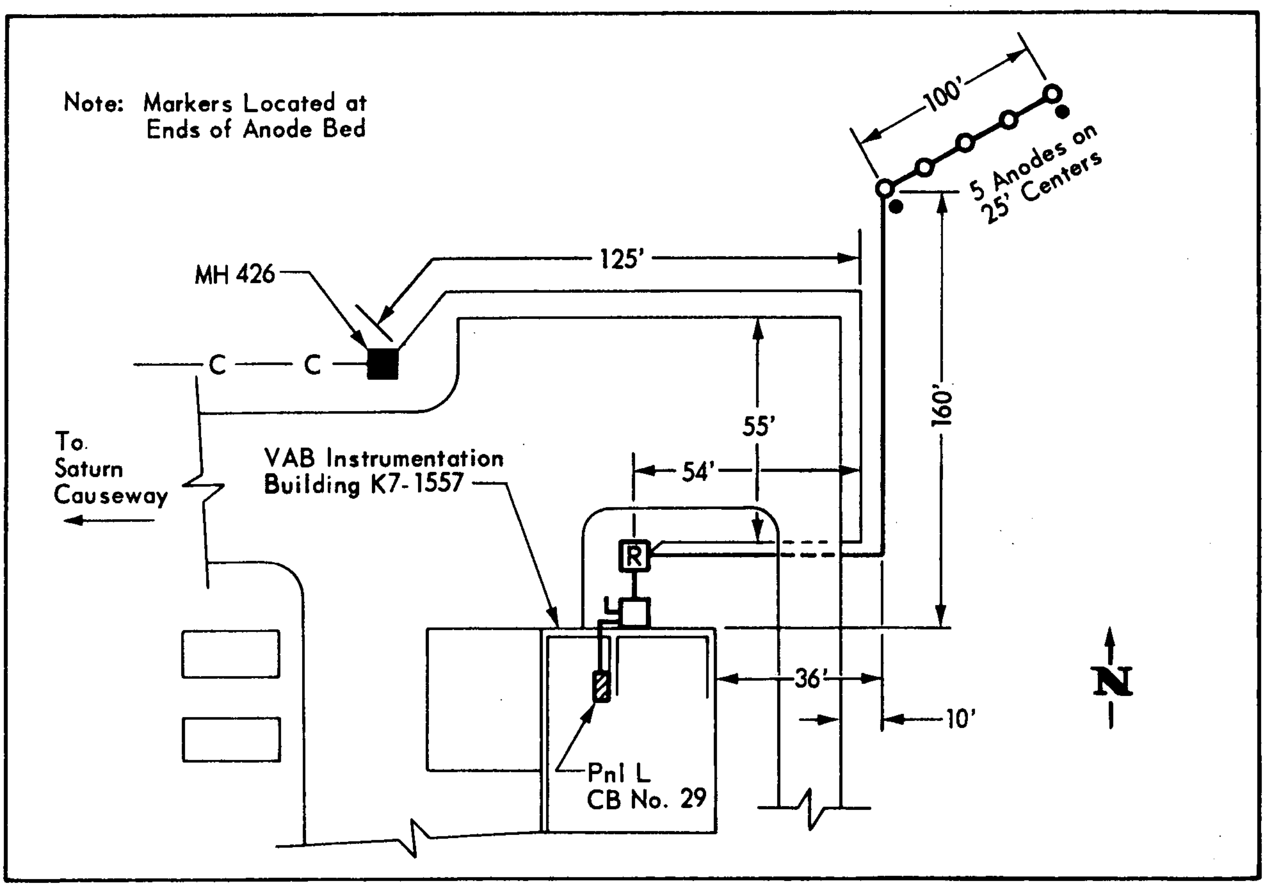


Figure 1-10. Site No. 8 Equipment Locator

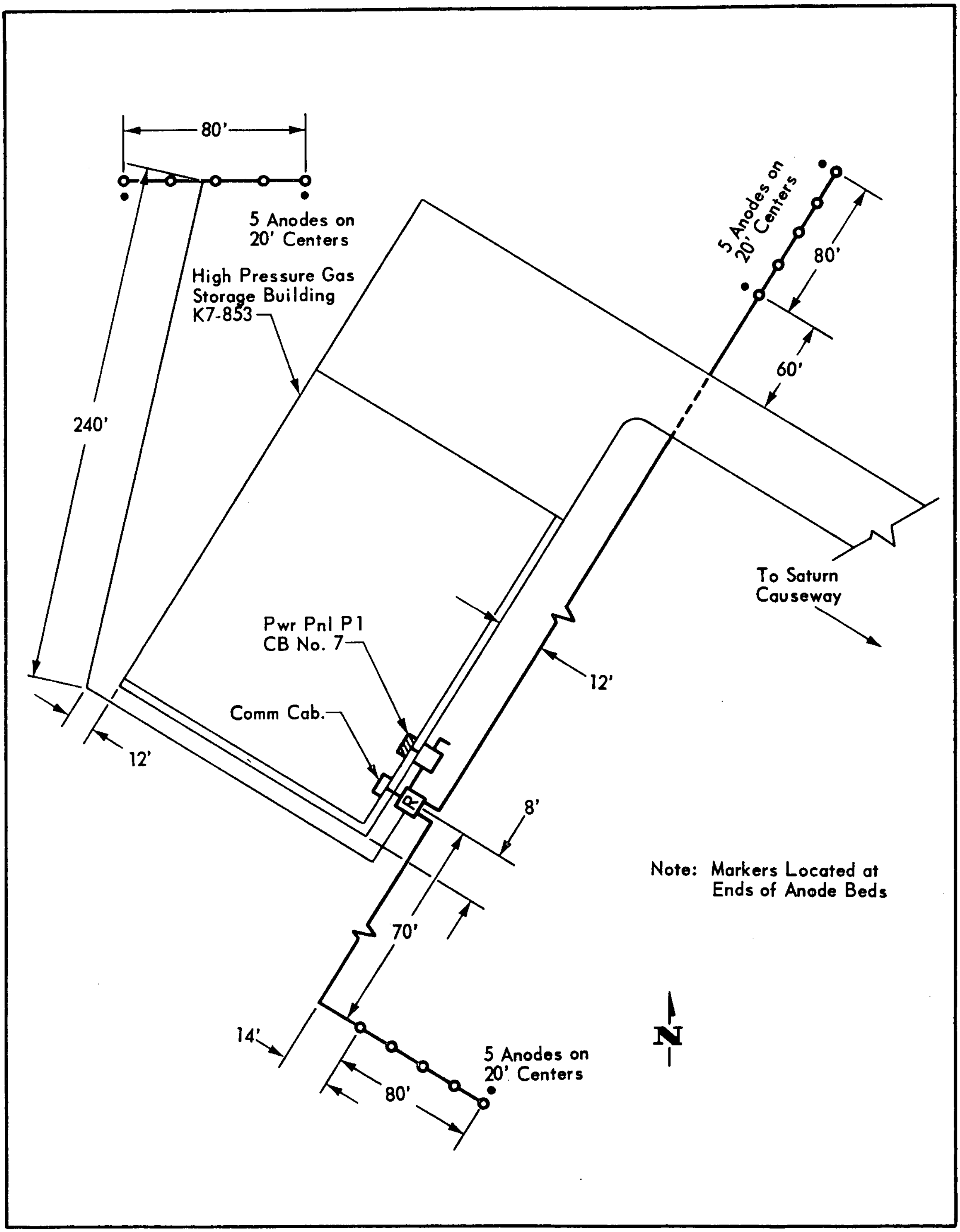


Figure 1-11. Site No. 10 Equipment Locator

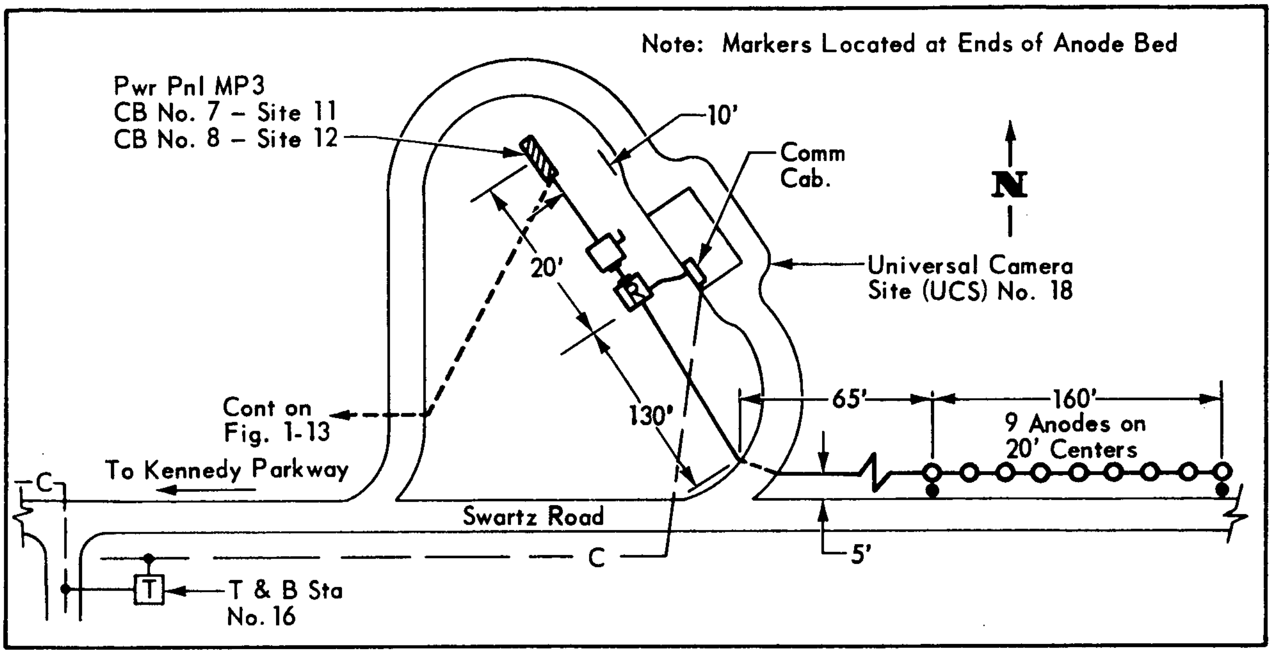


Figure 1-12. Site No. 11 and Test and Bond Station No. 16 Equipment Locator

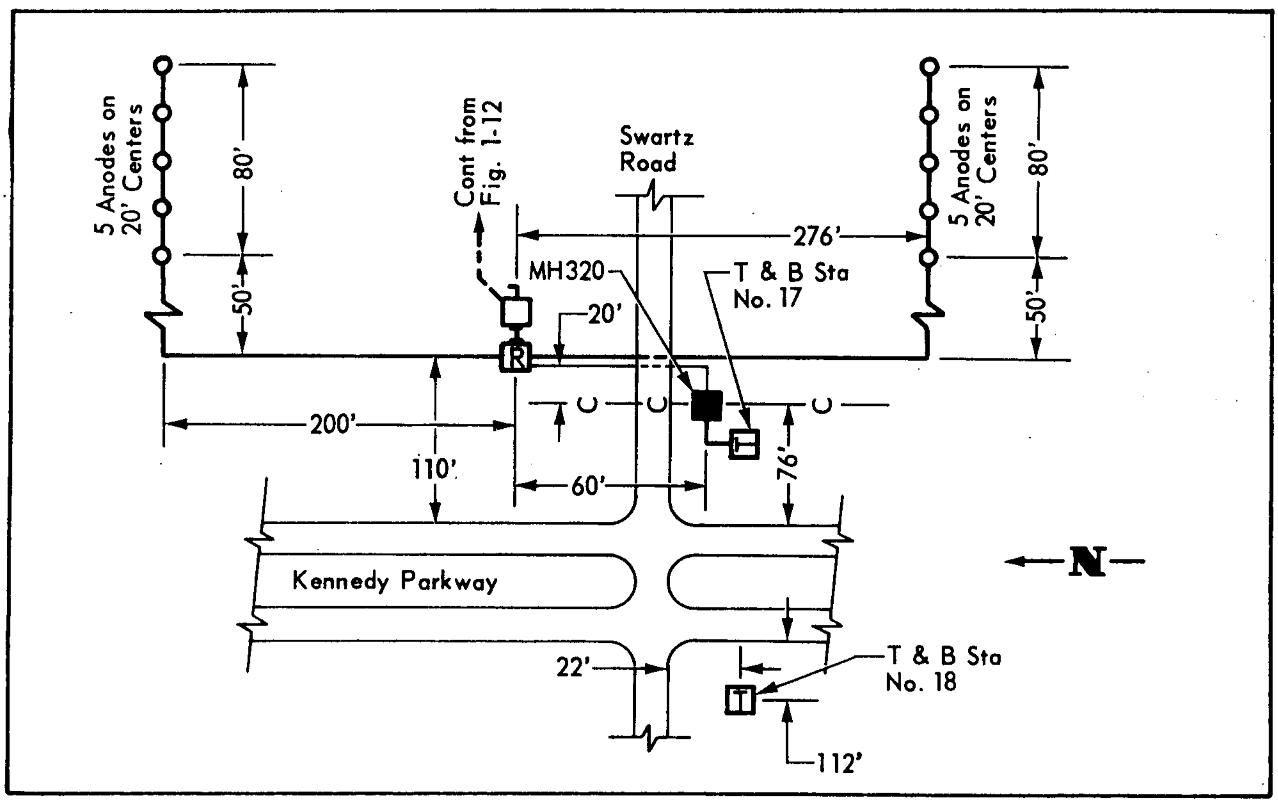


Figure 1-13. Site No. 12 and Test and Bond Stations No. 17 and 18 Equipment Locator

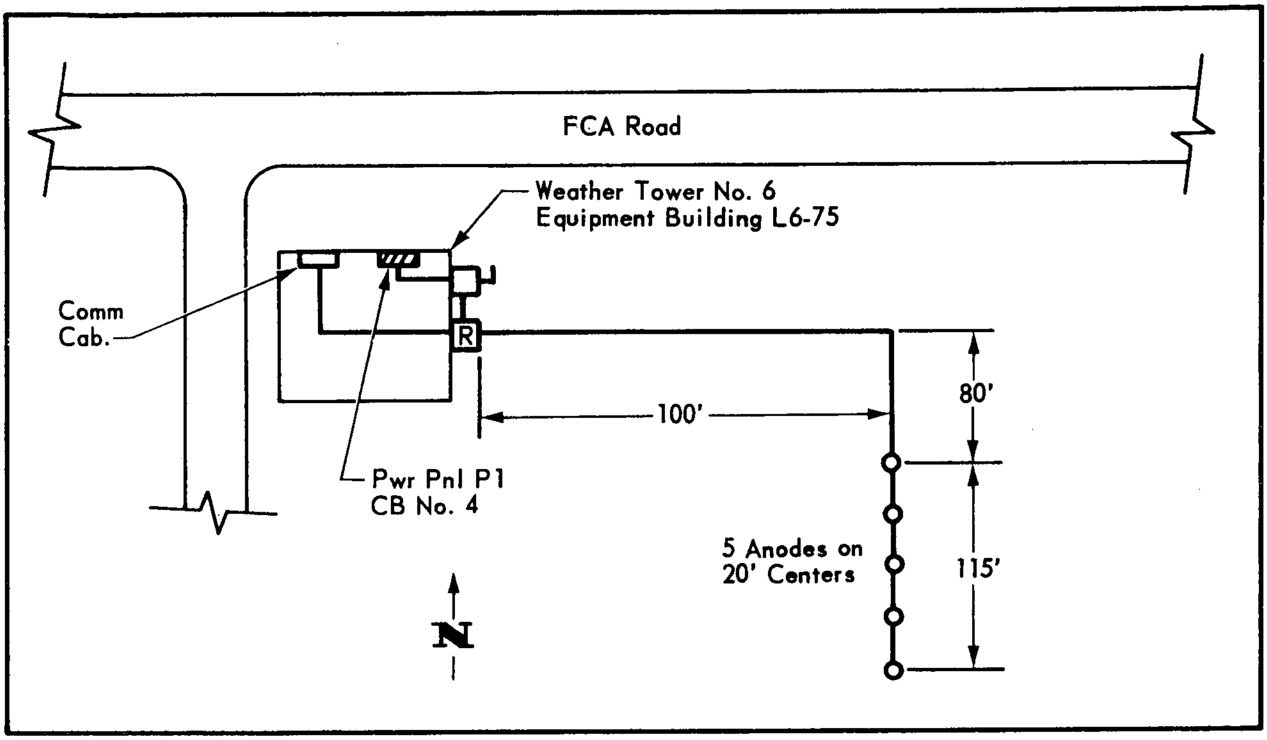


Figure 1-14. Site No. 13 Equipment Locator

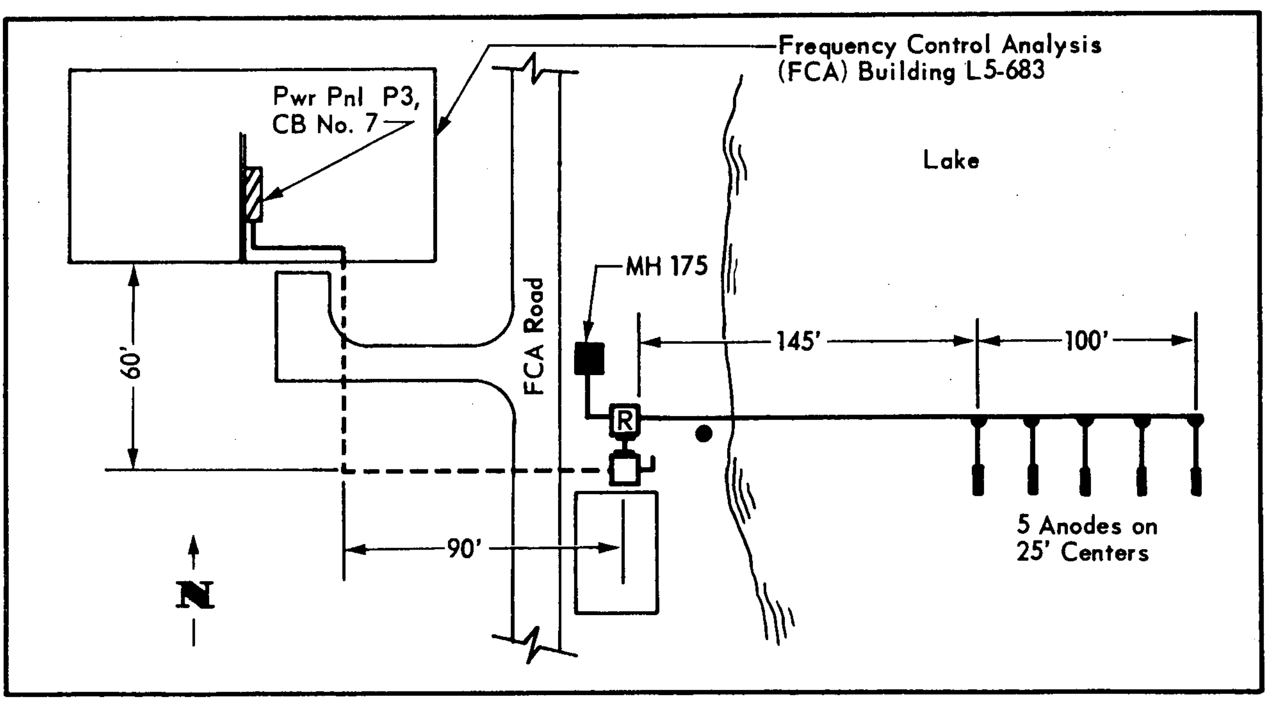


Figure 1-15. Site No. 14 Equipment Locator

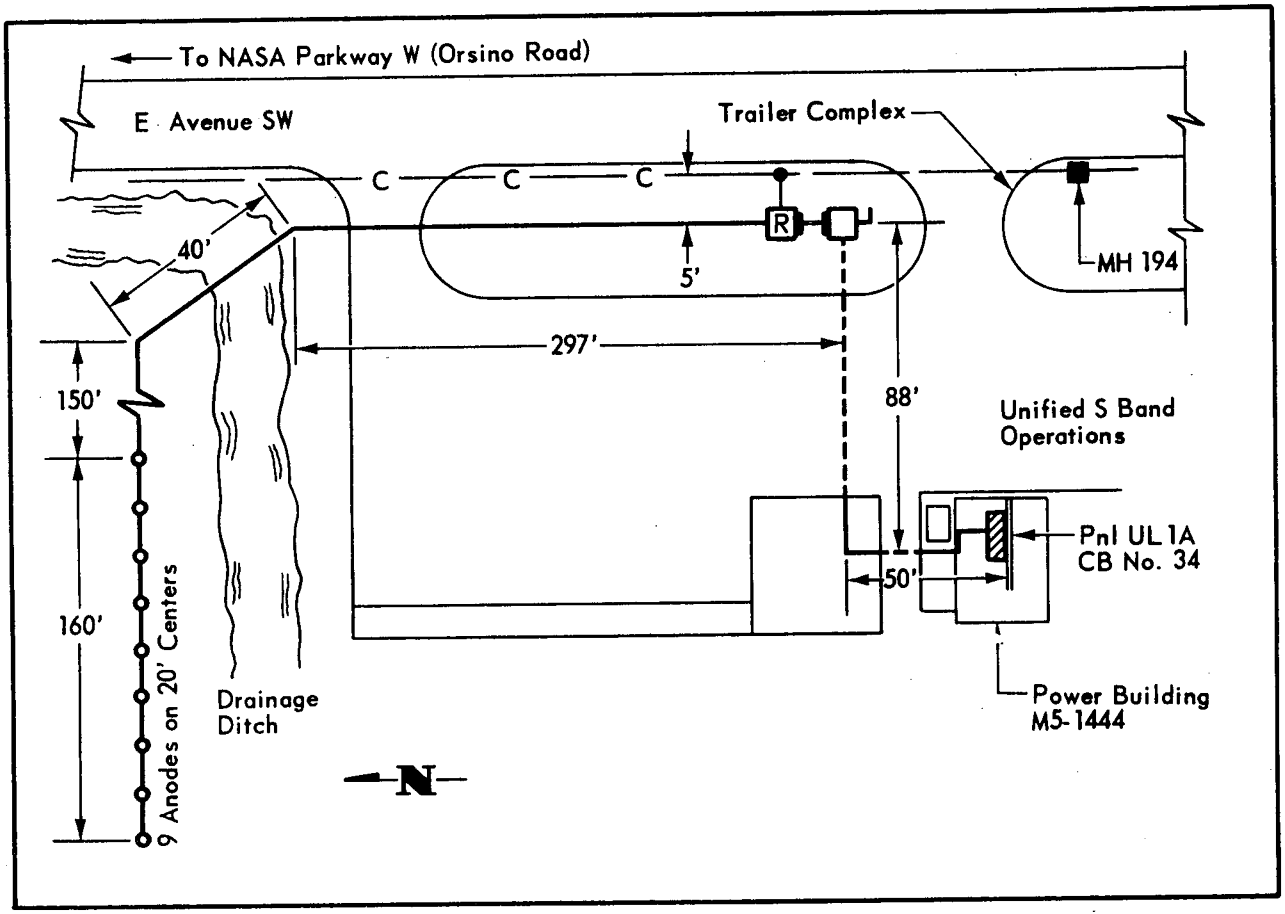


Figure 1-16. Site No. 16 Equipment Locator

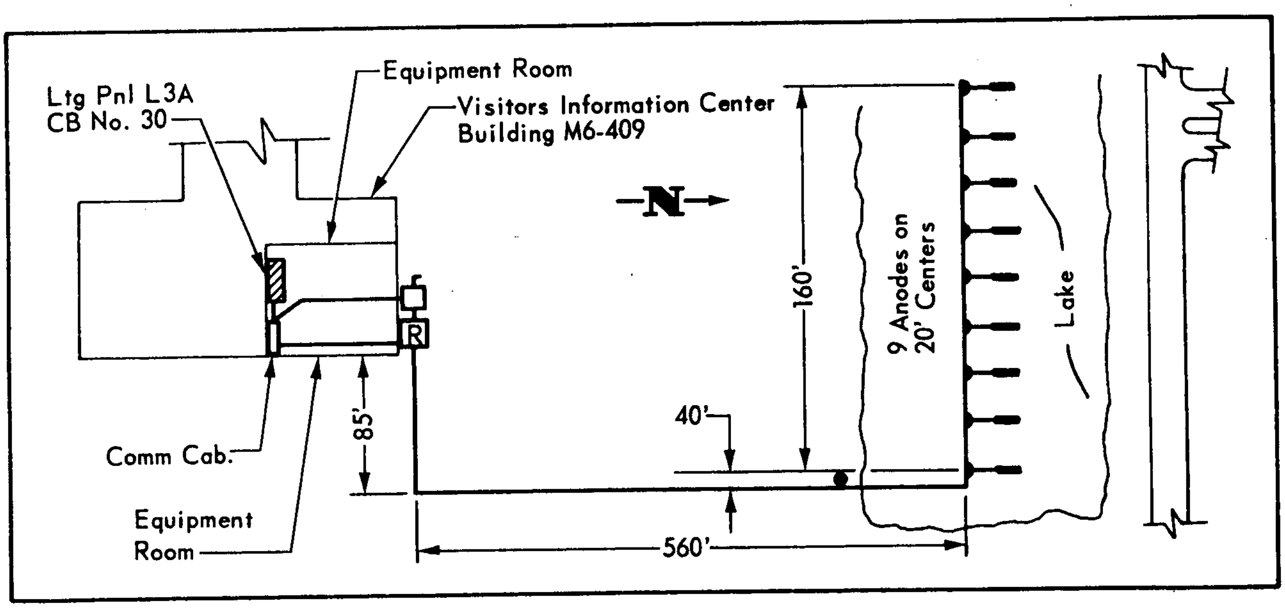


Figure 1-17. Site No. 17 Equipment Locator

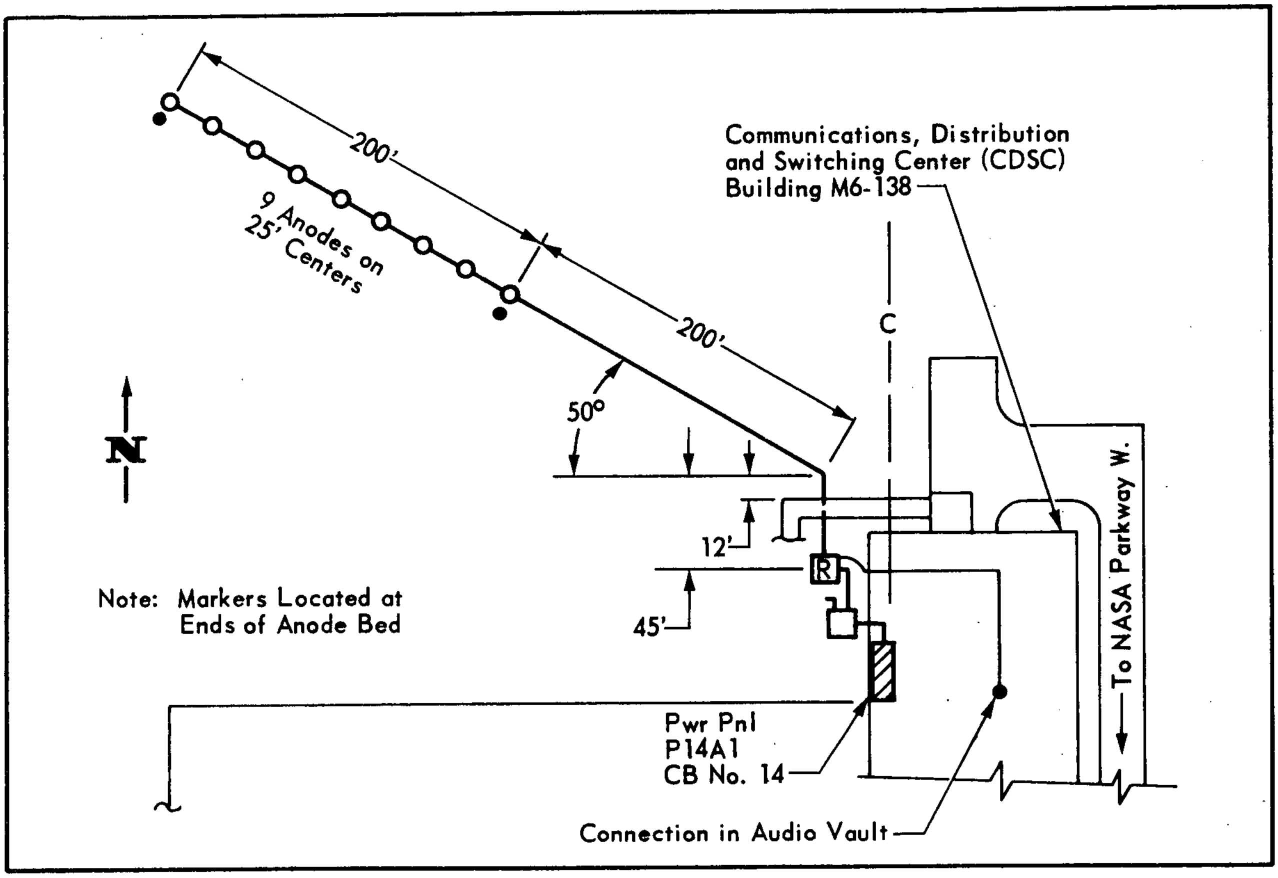


Figure 1-18. Site No. 18 Equipment Locator

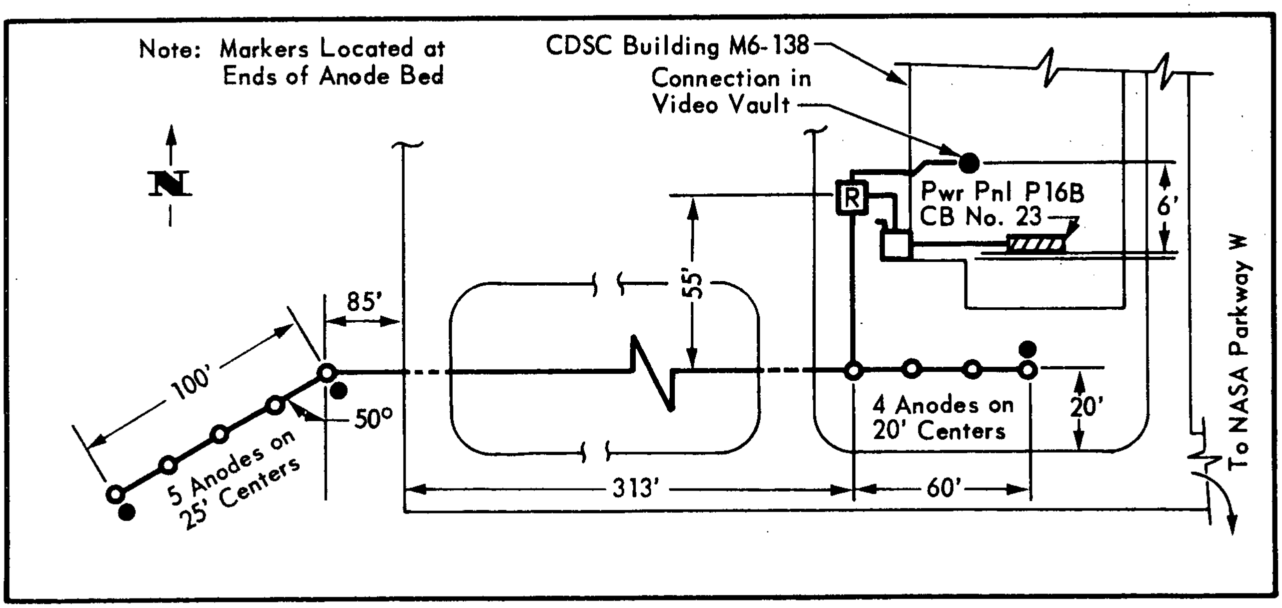


Figure 1-19. Site No. 19 Equipment Locator

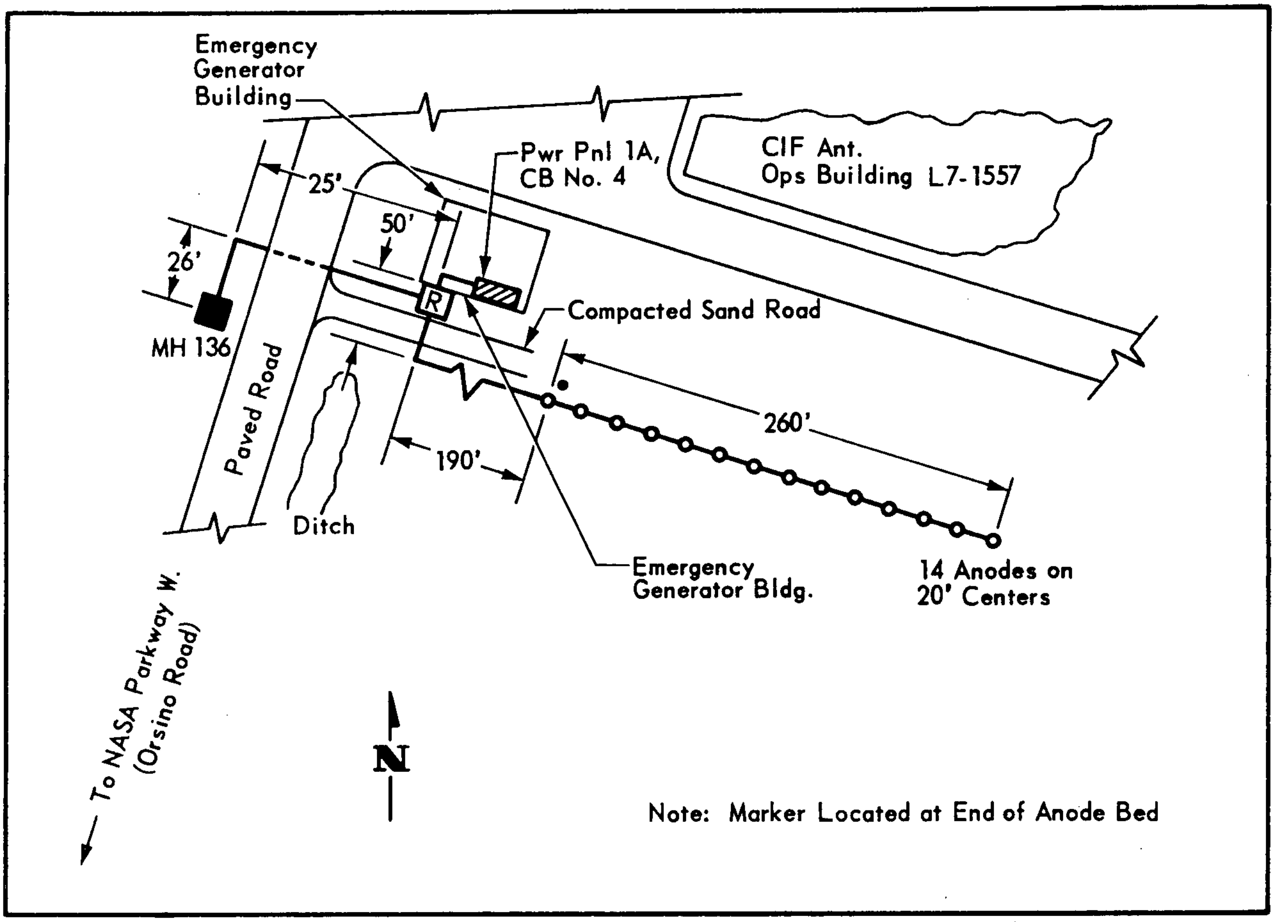


Figure 1-20. Site No. 20 Equipment Locator

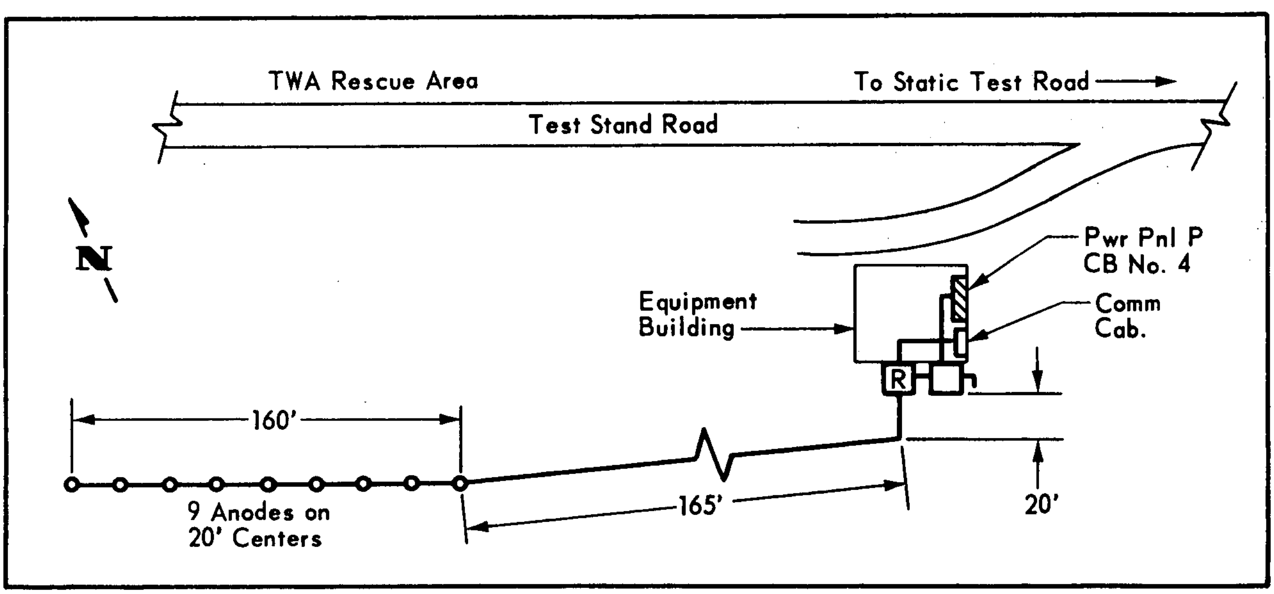
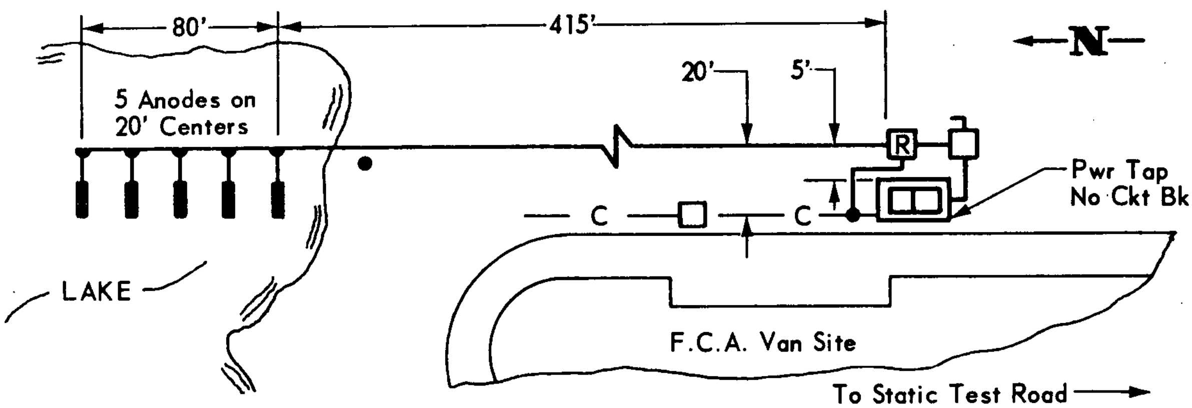


Figure 1-21. Site No. 21 Equipment Locator



Notes: Site Located East of Static Test Road North of NASA Parkway

Figure 1-22. Site No. 22 Equipment Locator

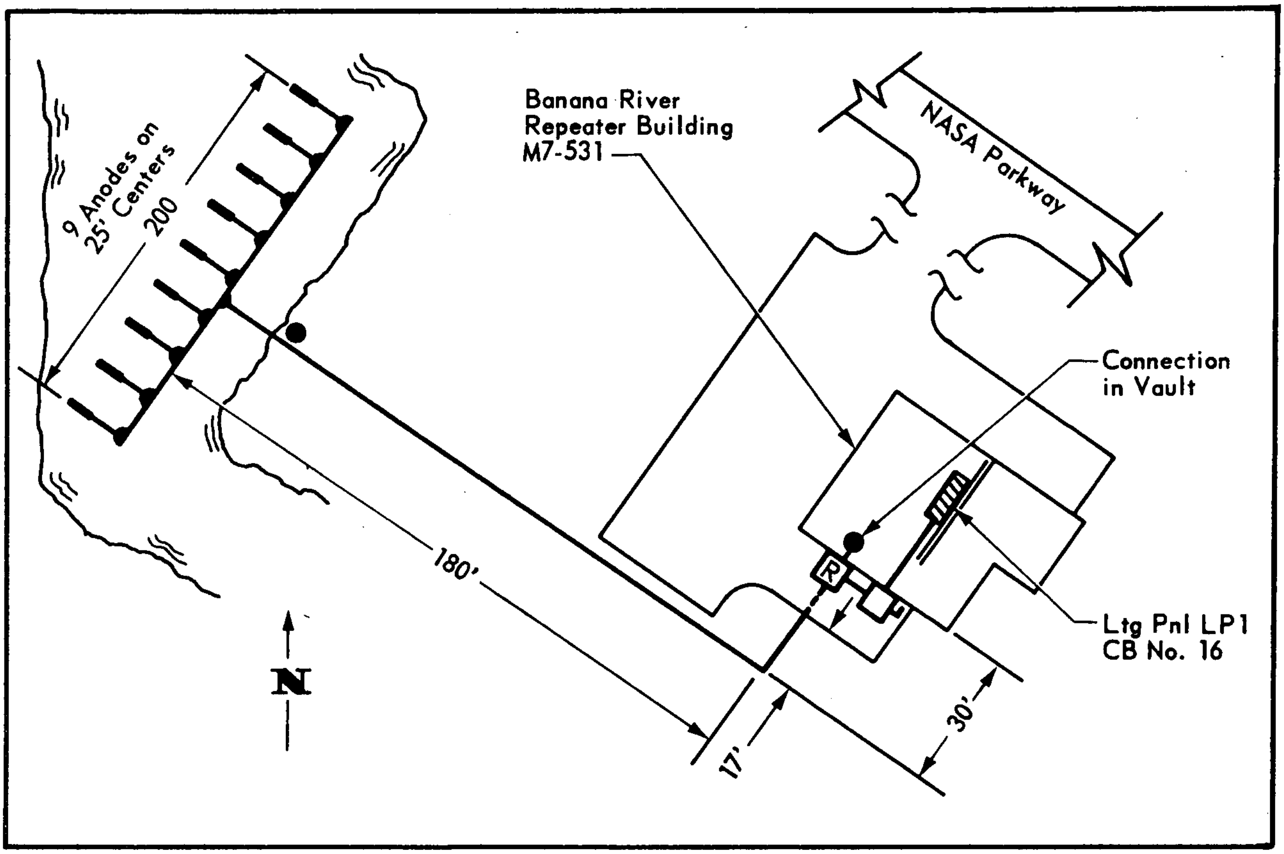


Figure 1-23. Site No. 23 Equipment Locator

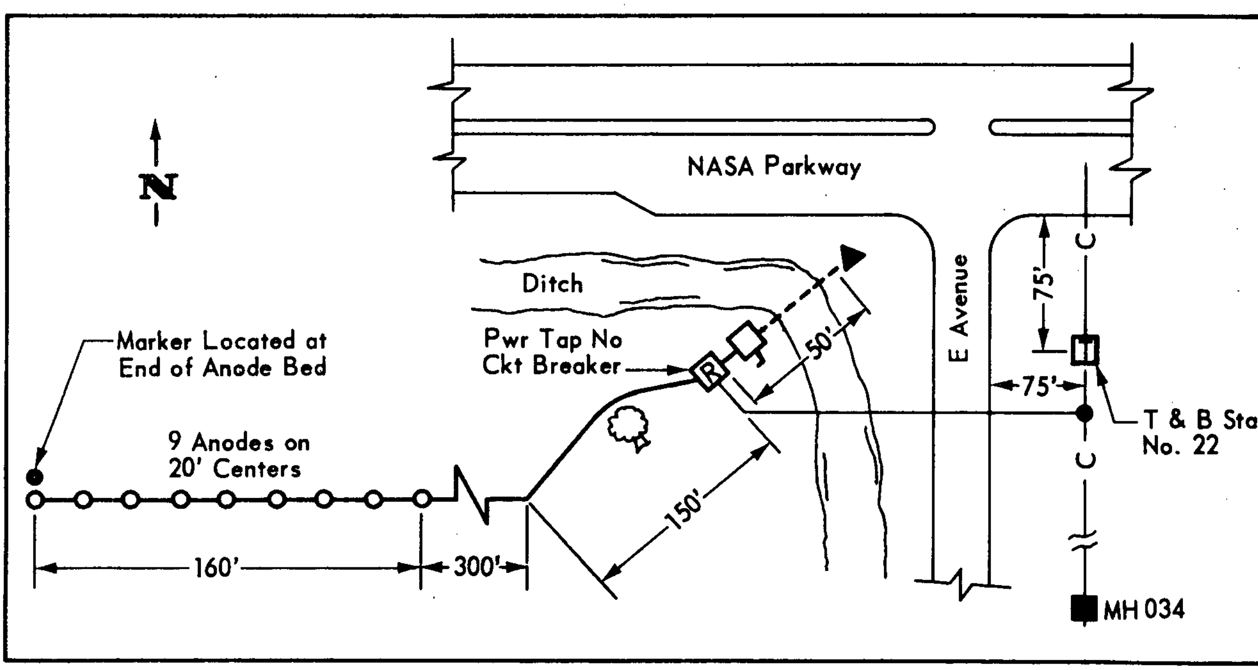


Figure 1-24. Site No. 24 and Test and Bond Station No. 22
Equipment Locator

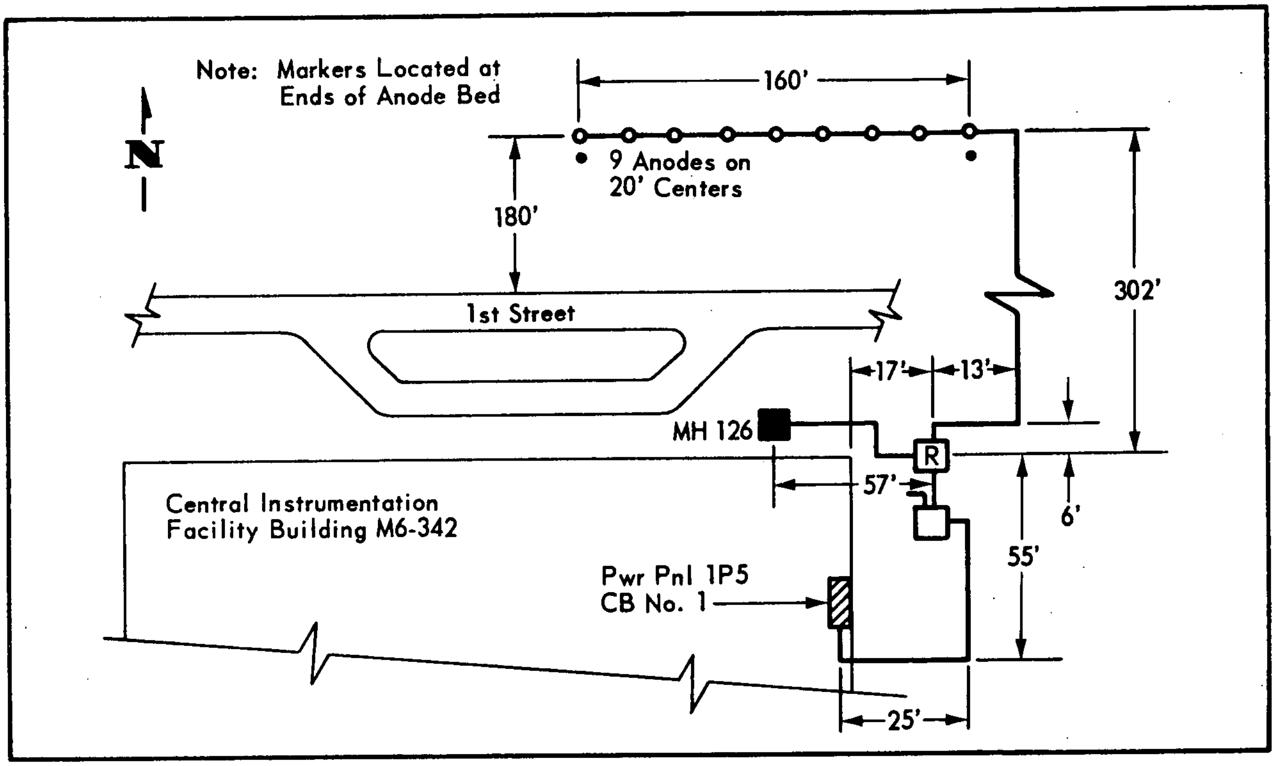


Figure 1-25. Site No. 25 Equipment Locator

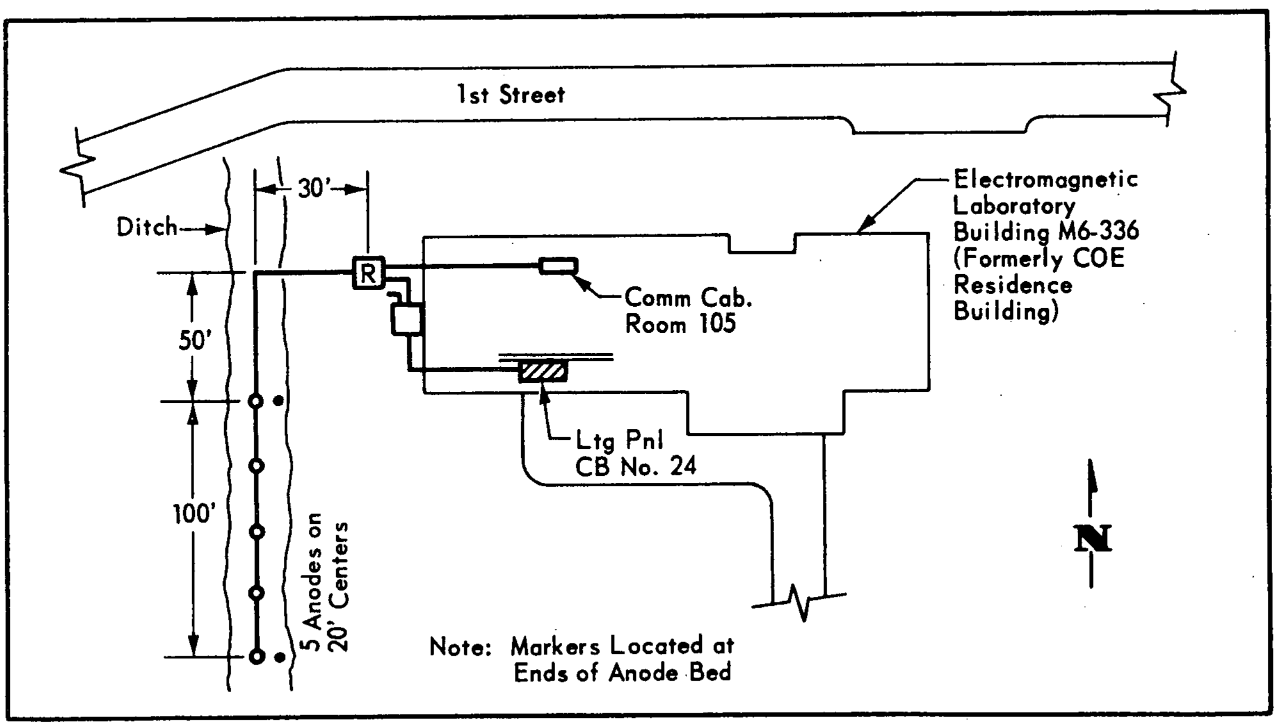


Figure 1-26. Site No. 26 Equipment Locator

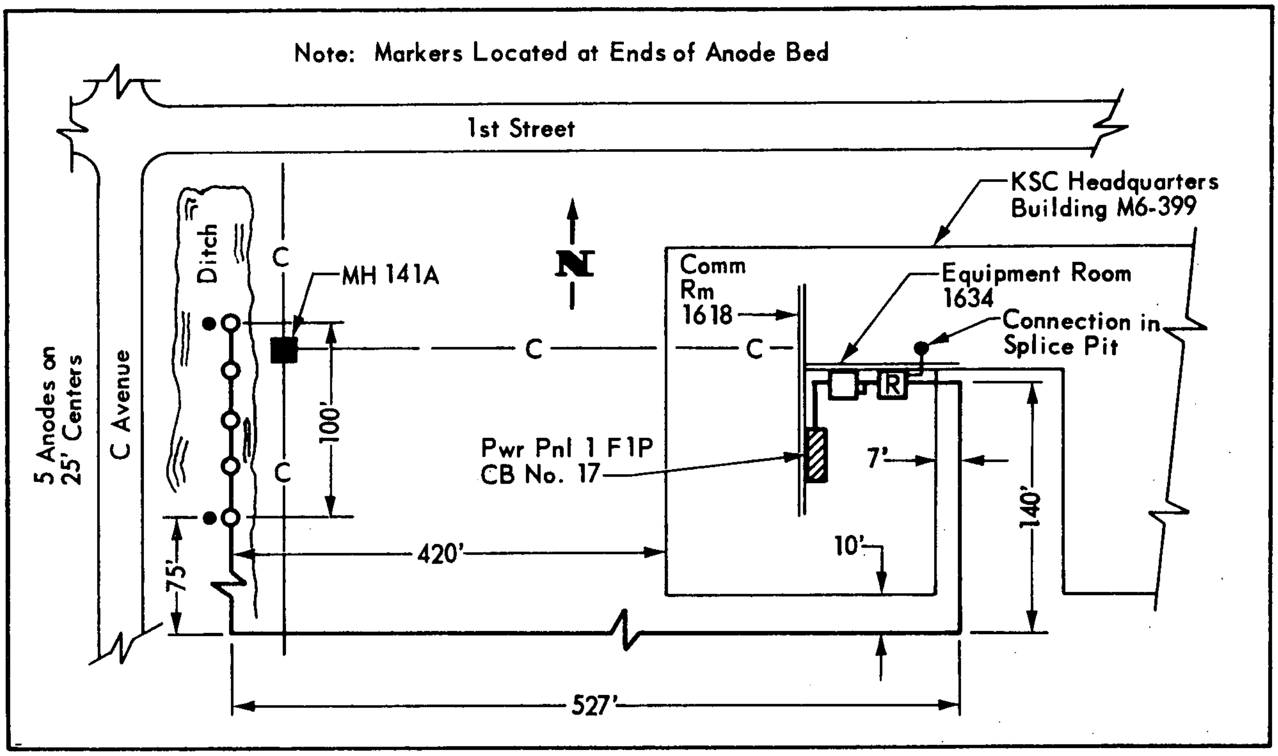


Figure 1-27. Site No. 27 Equipment Locator

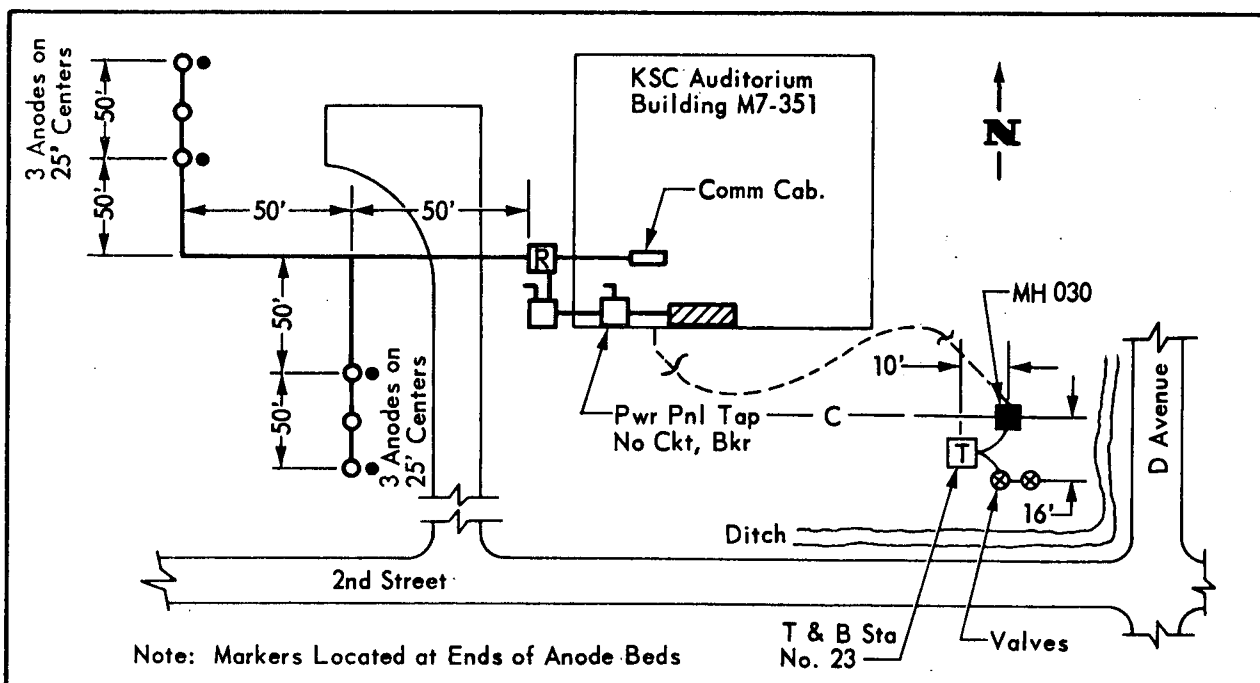


Figure 1-28. Site No. 28 and Test and Bond Station No. 23 Equipment Locator

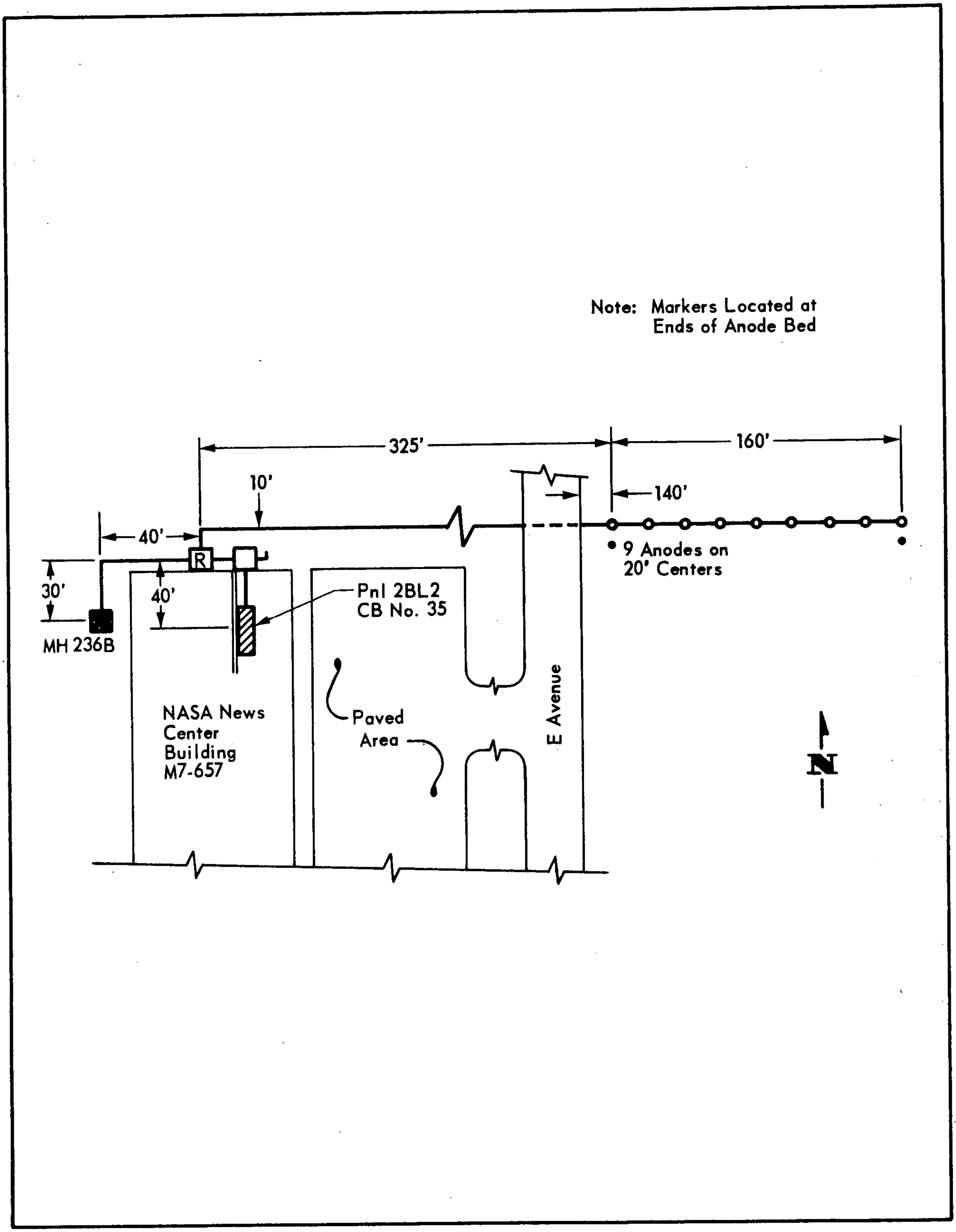


Figure 1-29. Site No. 29 Equipment Locator

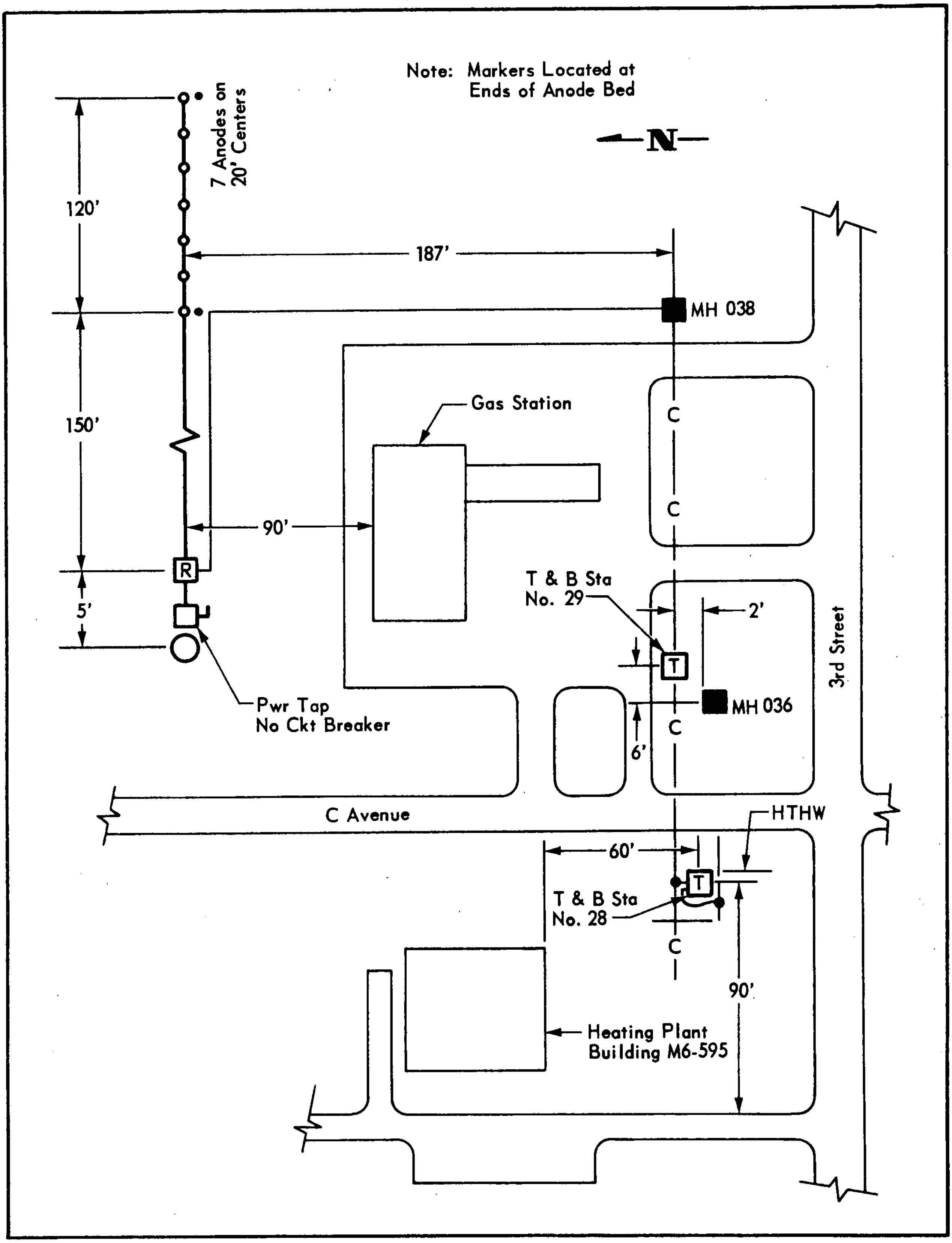


Figure 1-30. Site No. 30 and Test and Bond Stations No. 28 and 29 Equipment Locator

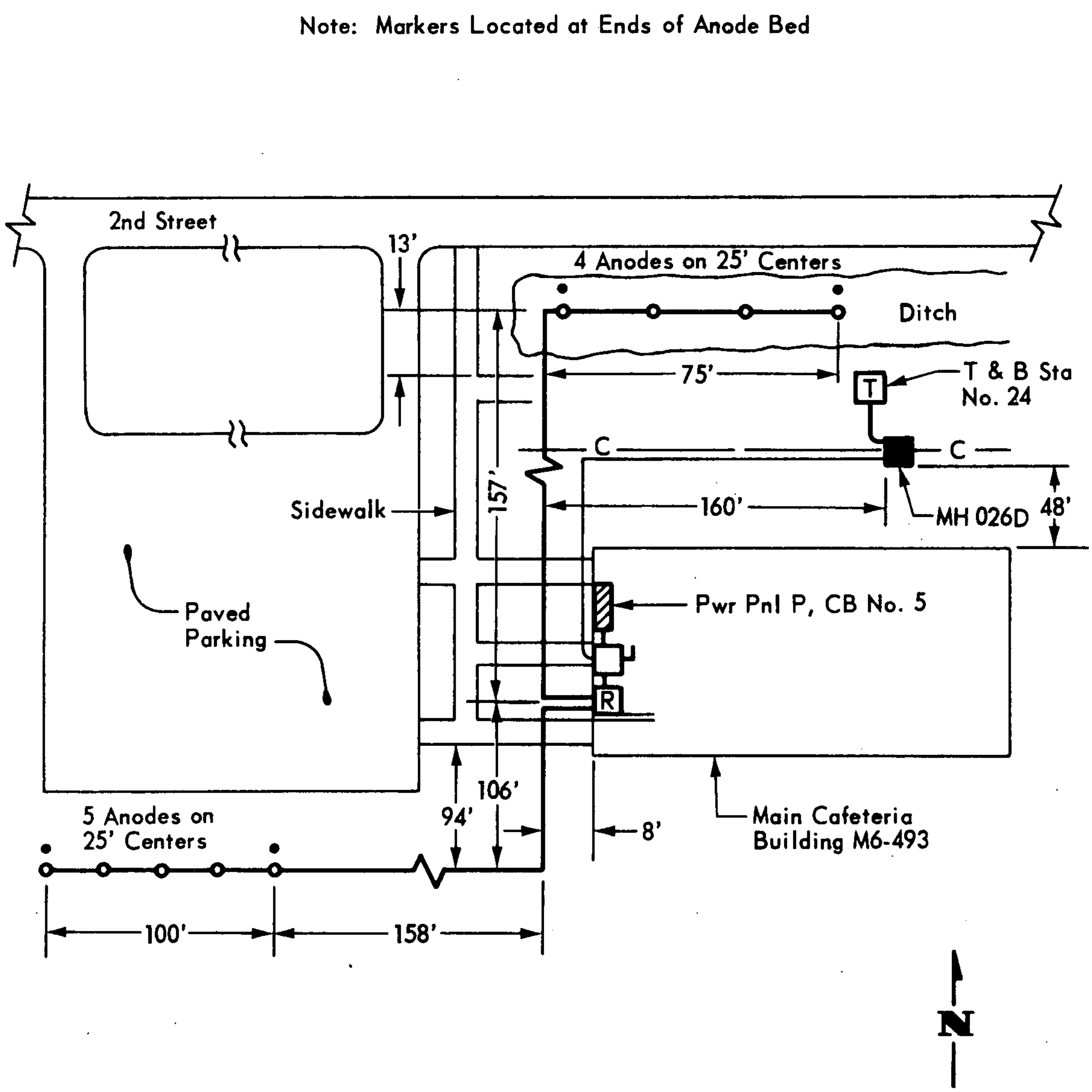


Figure 1-31. Site No. 31 and Test and Station No. 24 Equipment Locator

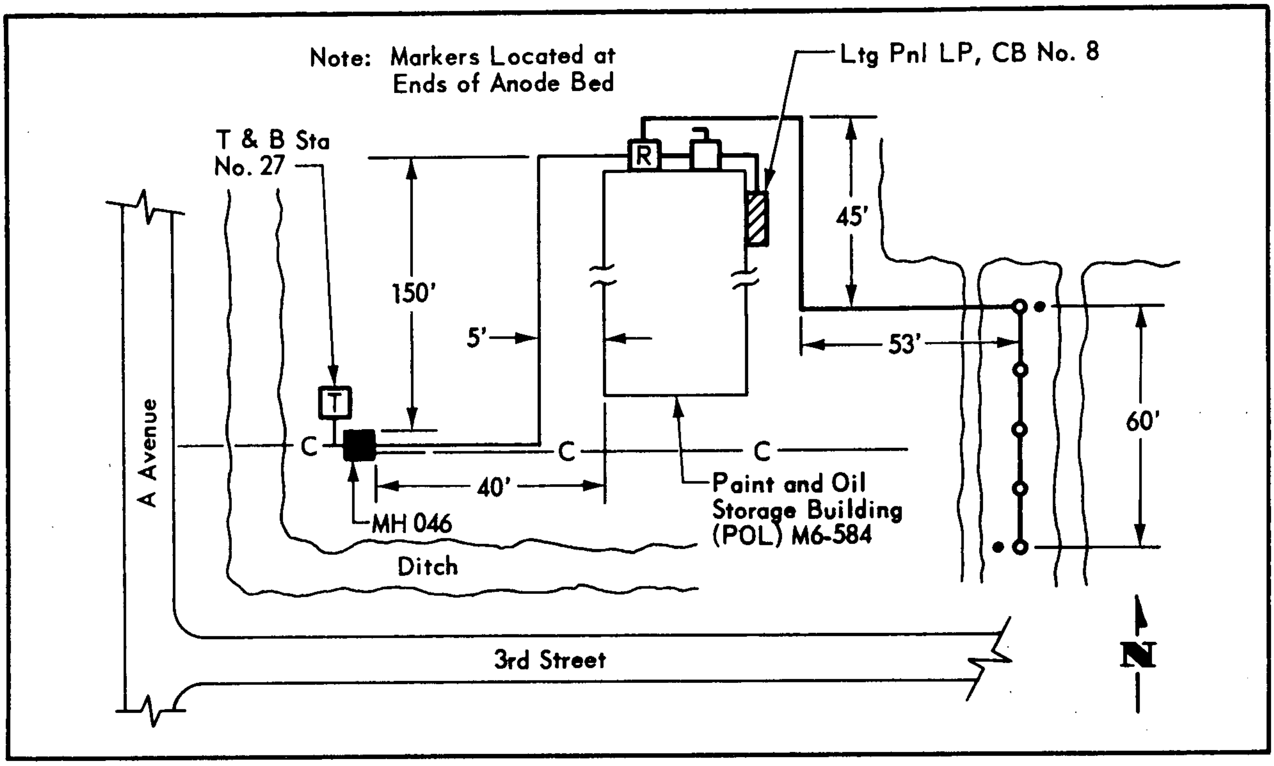


Figure 1-32. Site No. 32 and Test and Bond Station No. 27 Equipment Locator

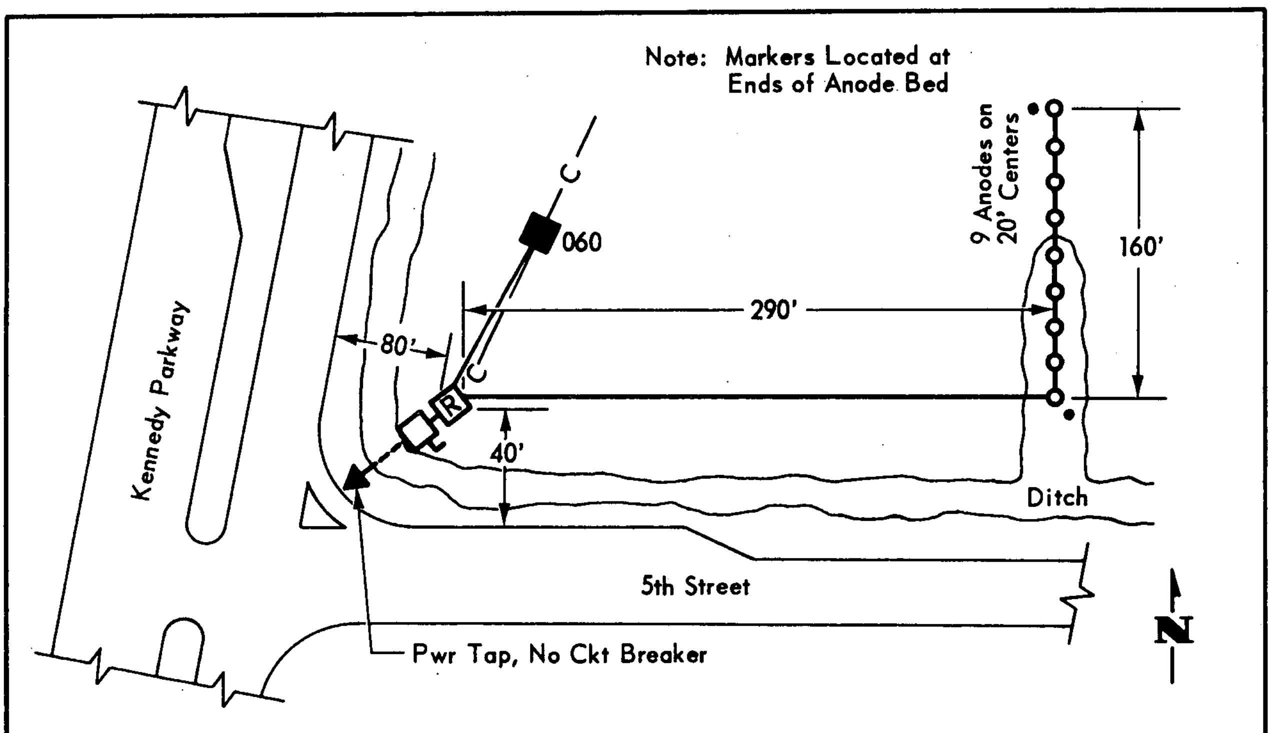


Figure 1-33. Site No. 33 Equipment Locator

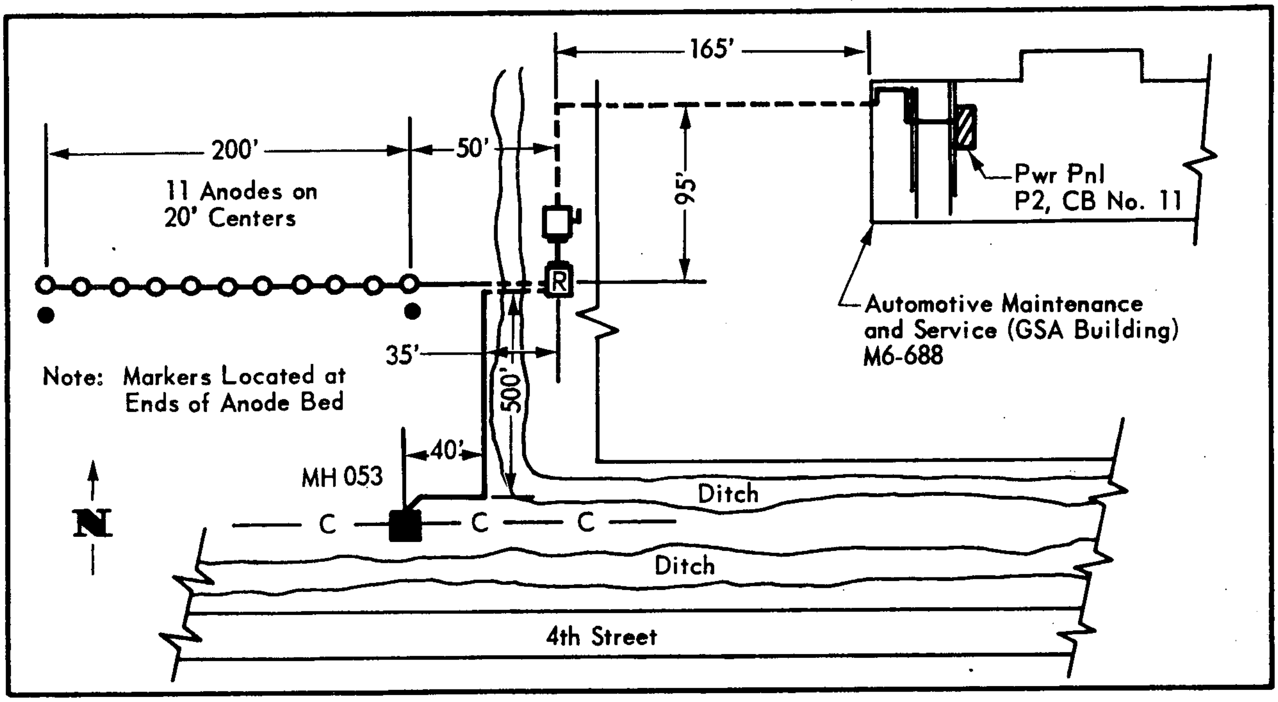


Figure 1-34. Site No. 34 Equipment Locator

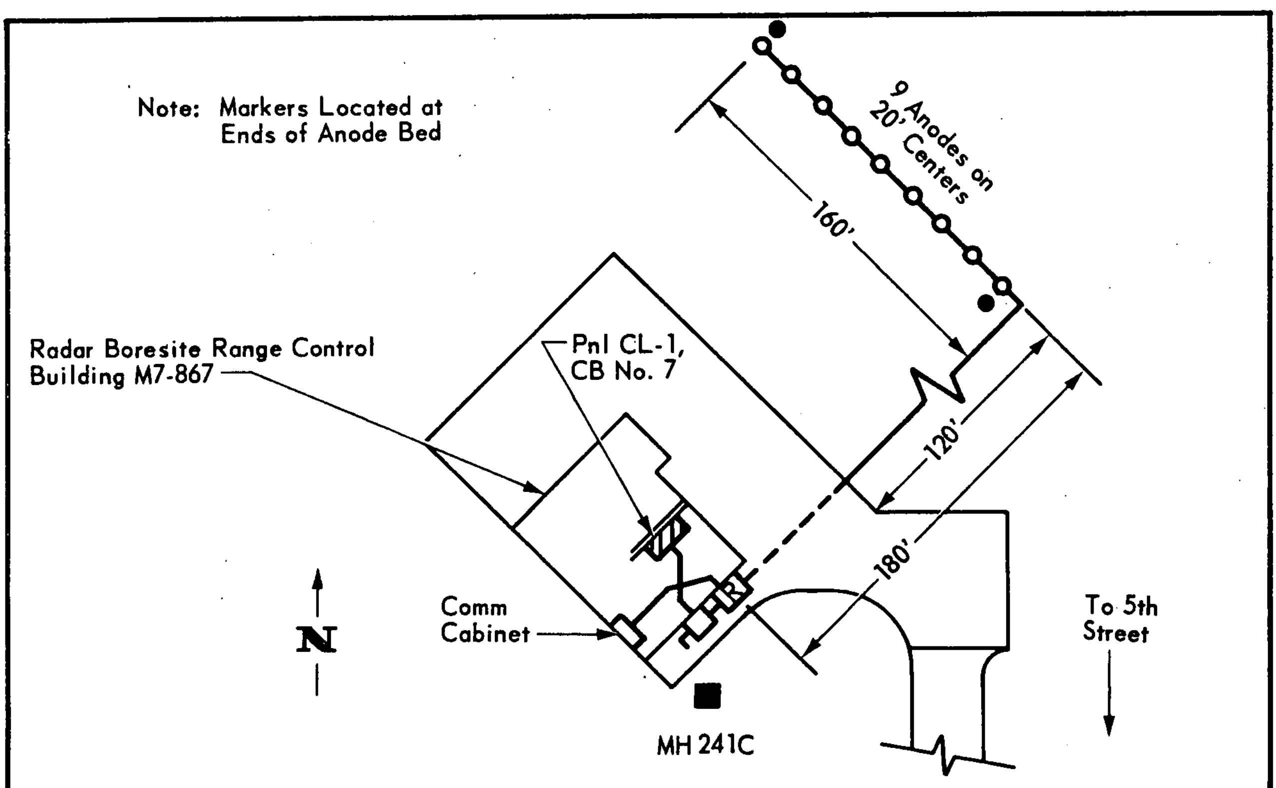


Figure 1-35. Site No. 35 Equipment Locator

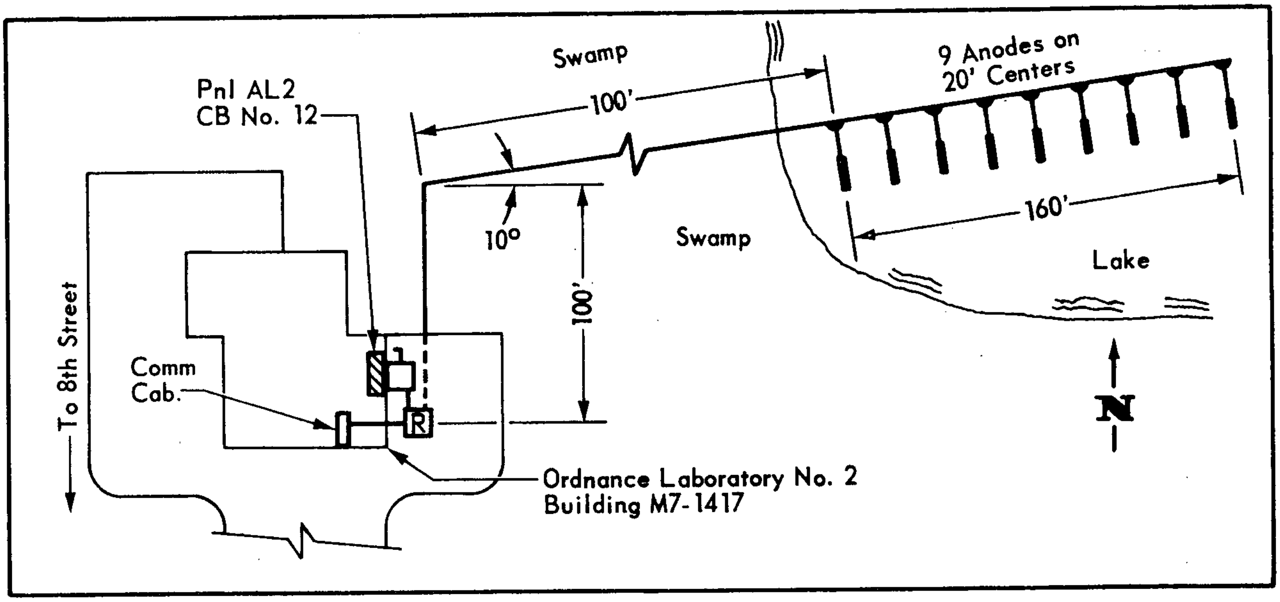


Figure 1-36. Site No. 36 Equipment Locator

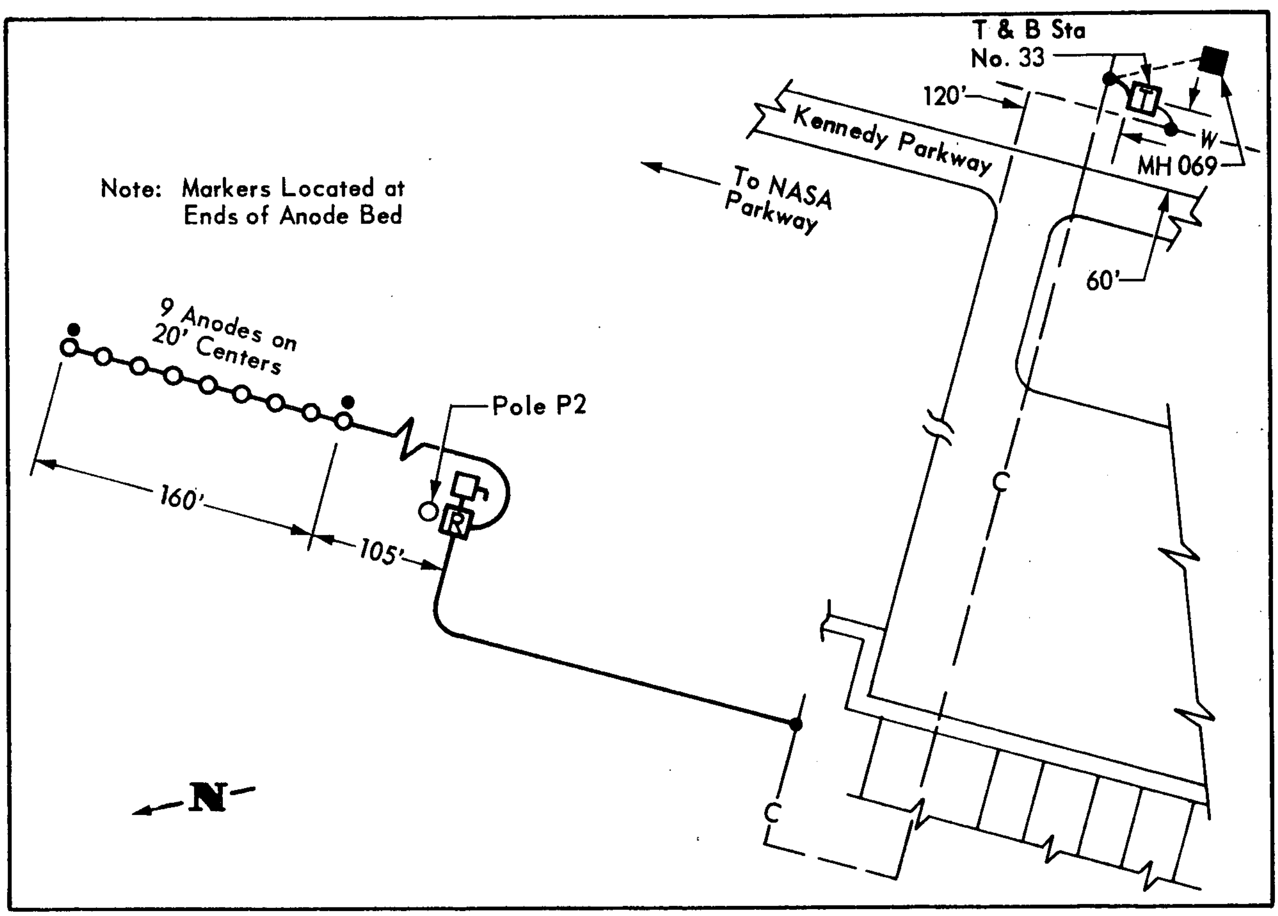


Figure 1-37. Site No. 37 and Test and Bond Station No. 33 Equipment Locator

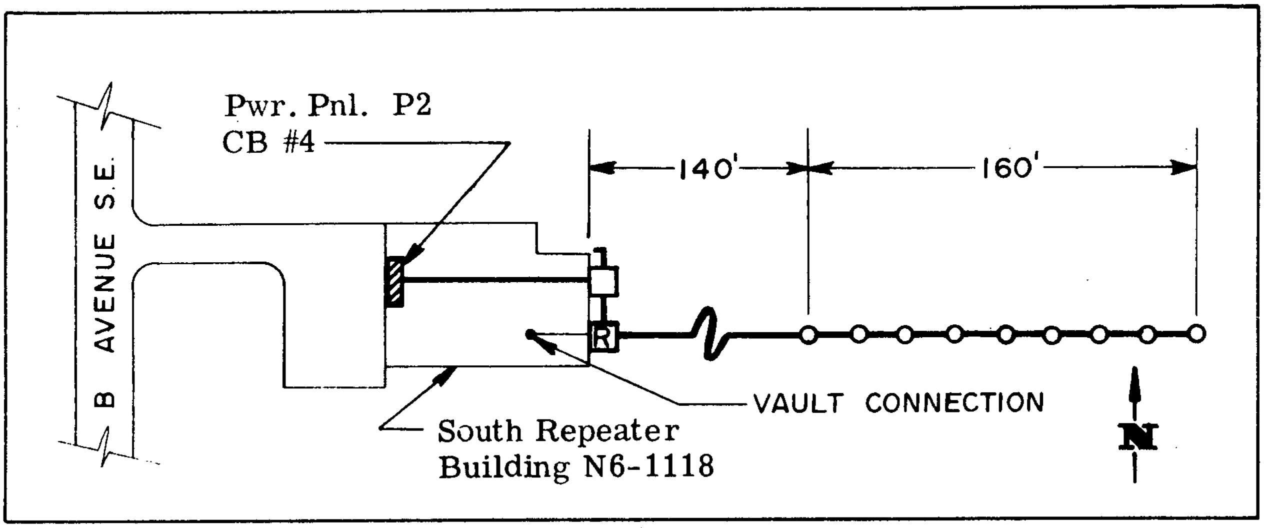


Figure 1-38. Site No. 38 Equipment Locator

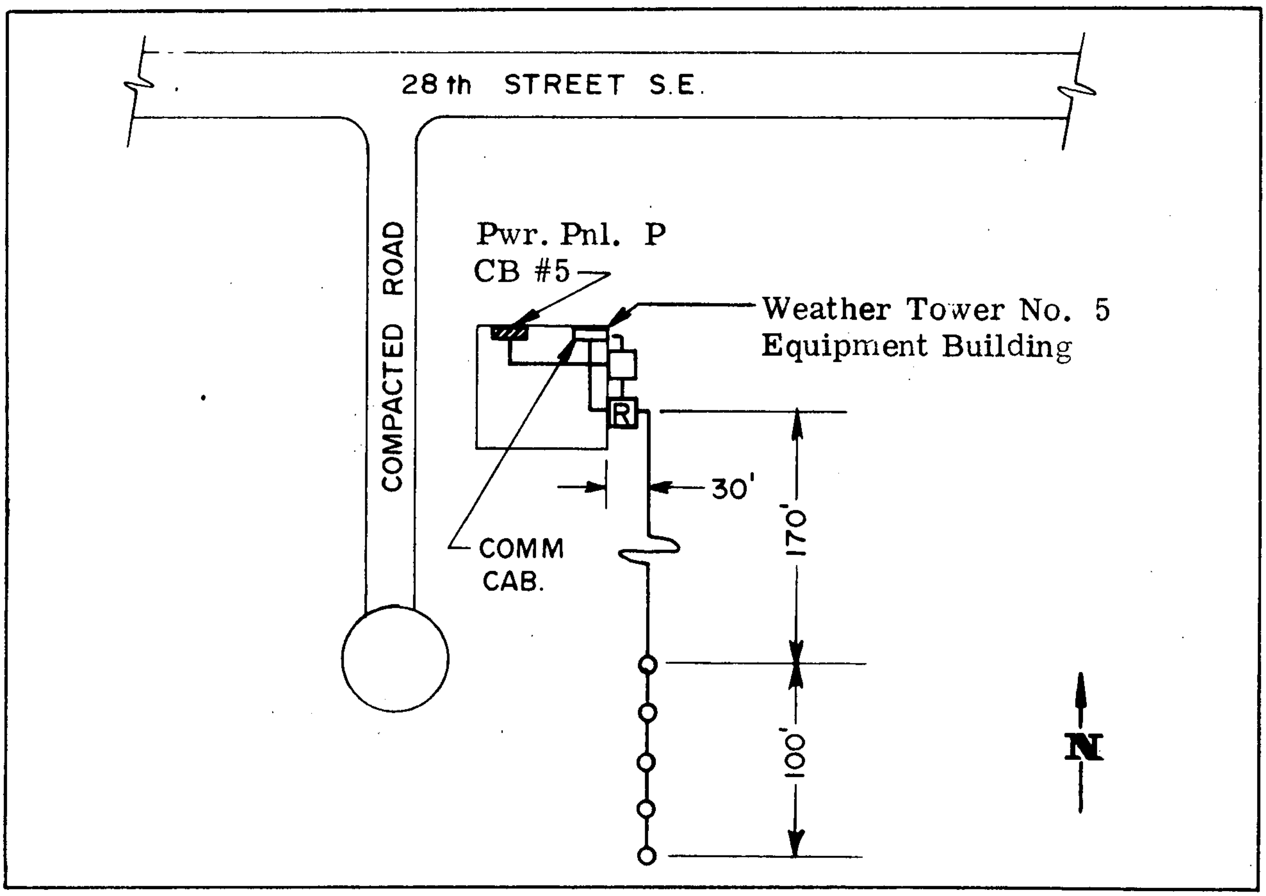


Figure 1-39. Site No. 39 Equipment Locator

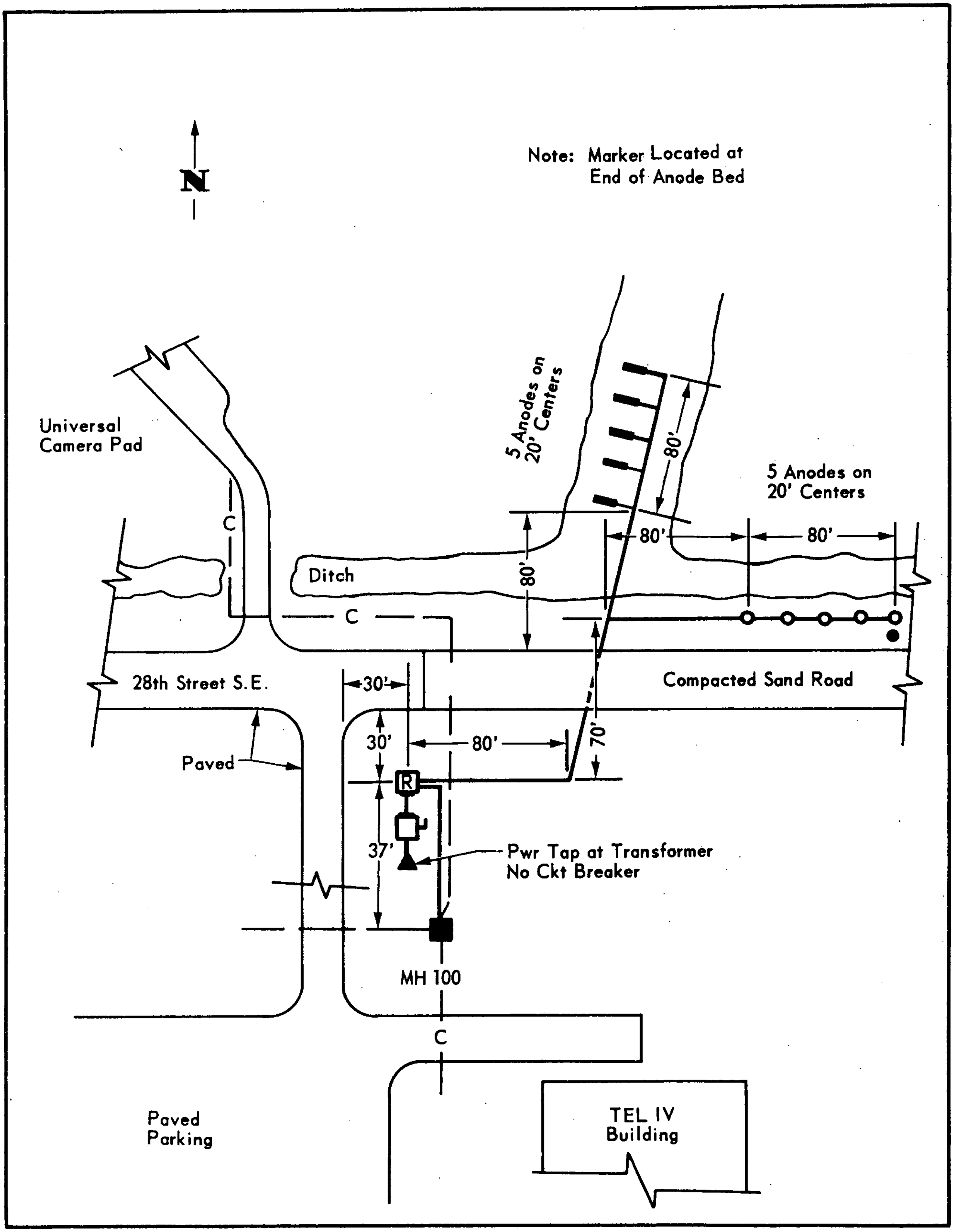


Figure 1-40. Site No. 40 Equipment Locator

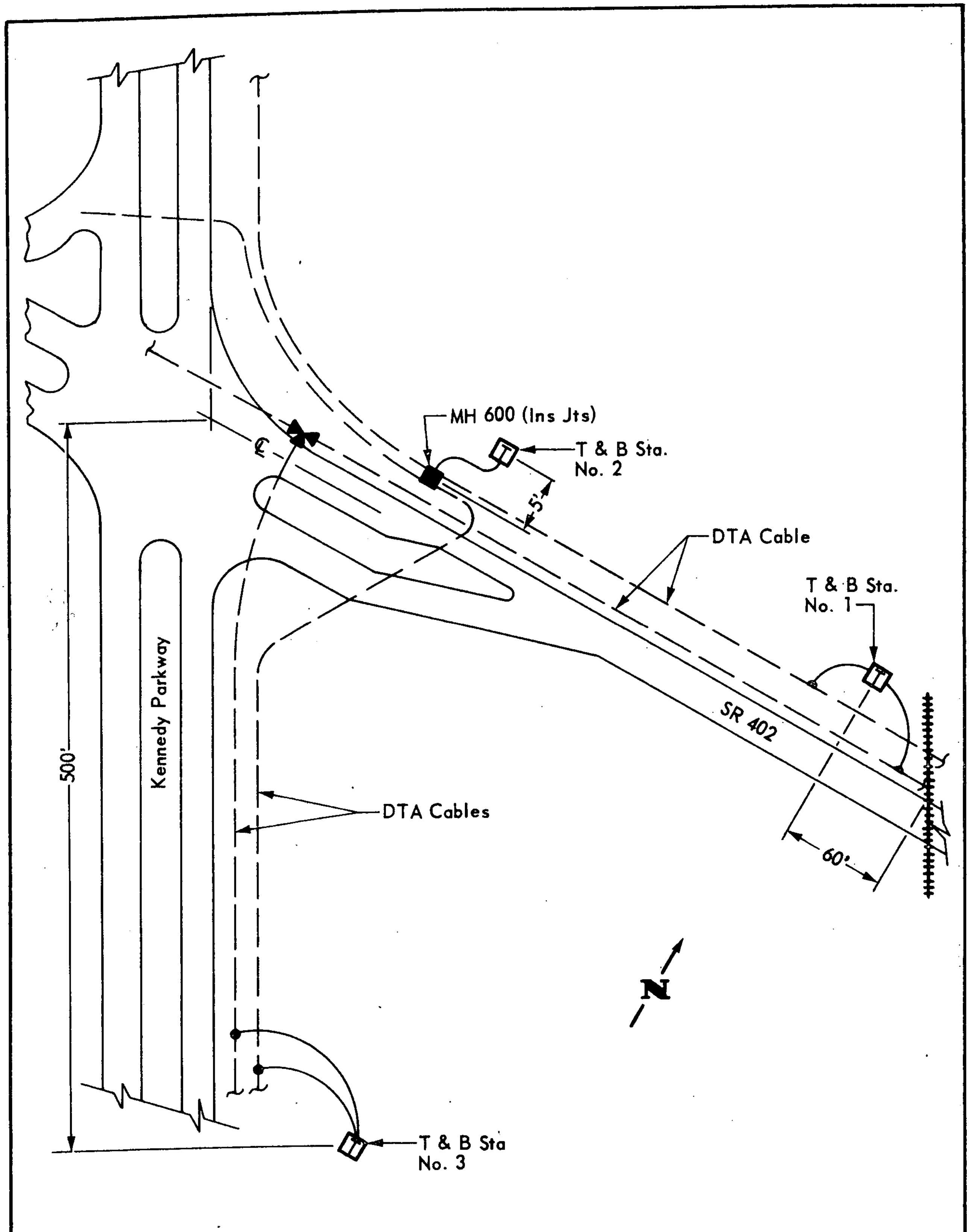


Figure 1-41. Test and Bond Stations No. 1, 2, and 3 Equipment Locator

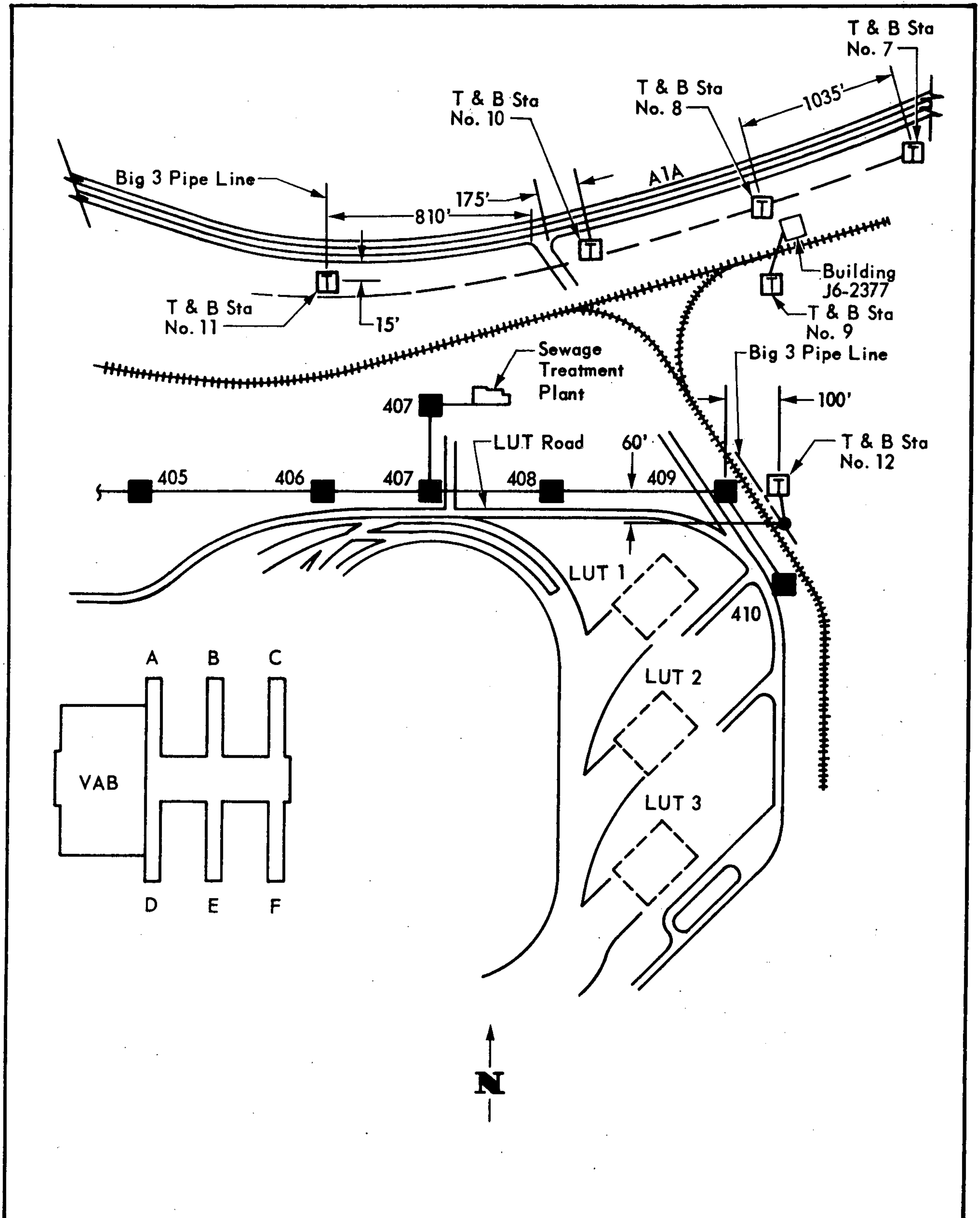


Figure 1-42. Test and Bond Stations No. 7, 8, 9, 10, 11, and 12 Equipment Locator

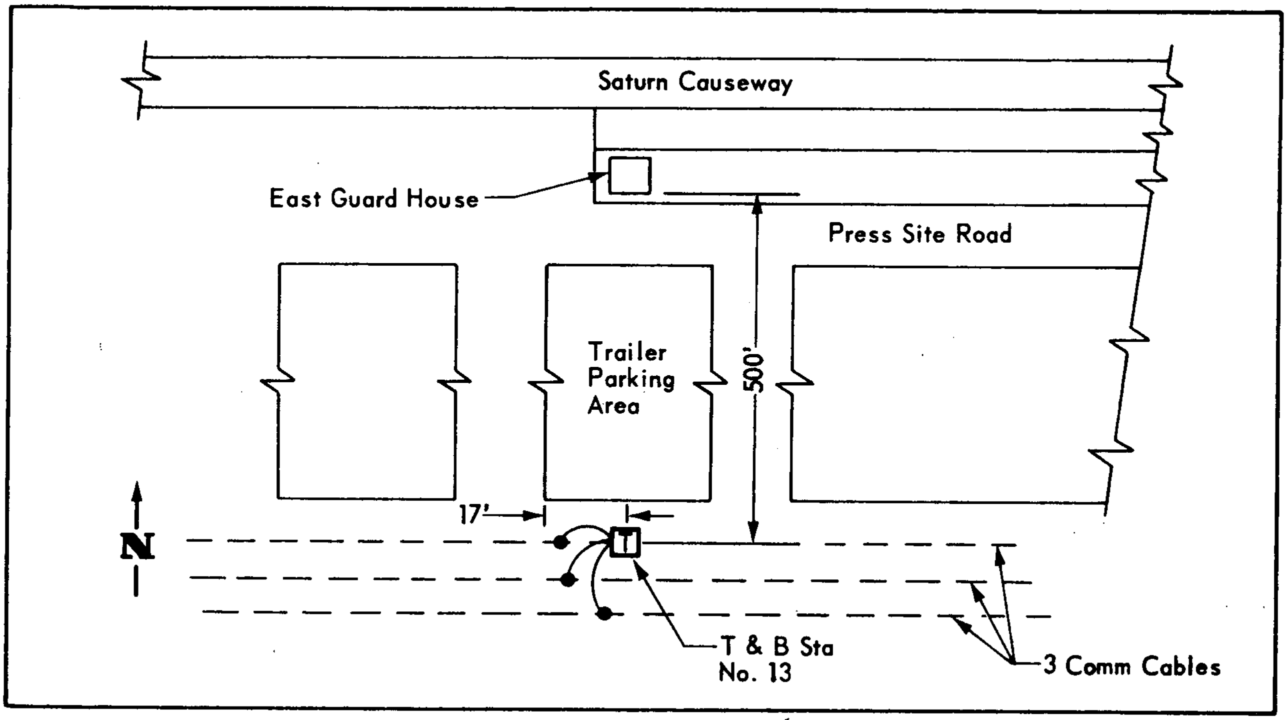


Figure 1-43. Test and Bond Station No. 13 Equipment Locator

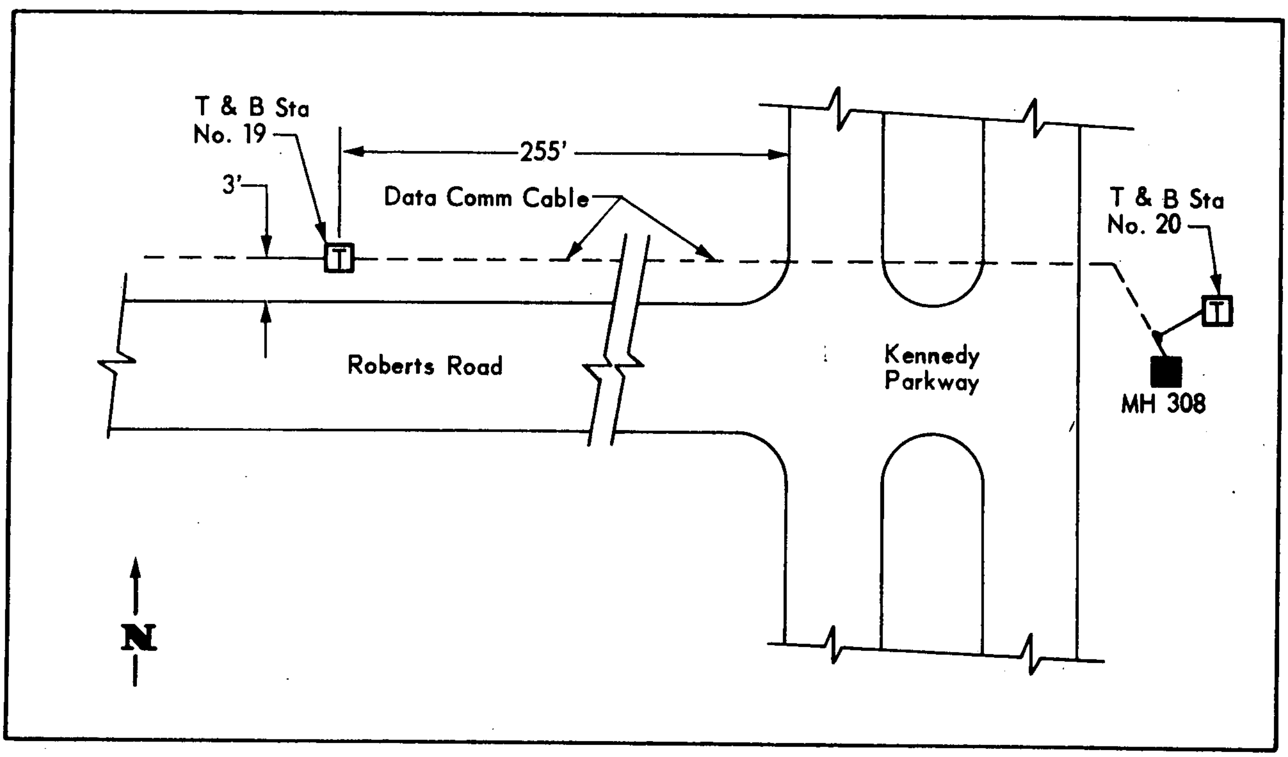


Figure 1-44. Test and Bond Stations No. 19 and 20 Equipment Locator

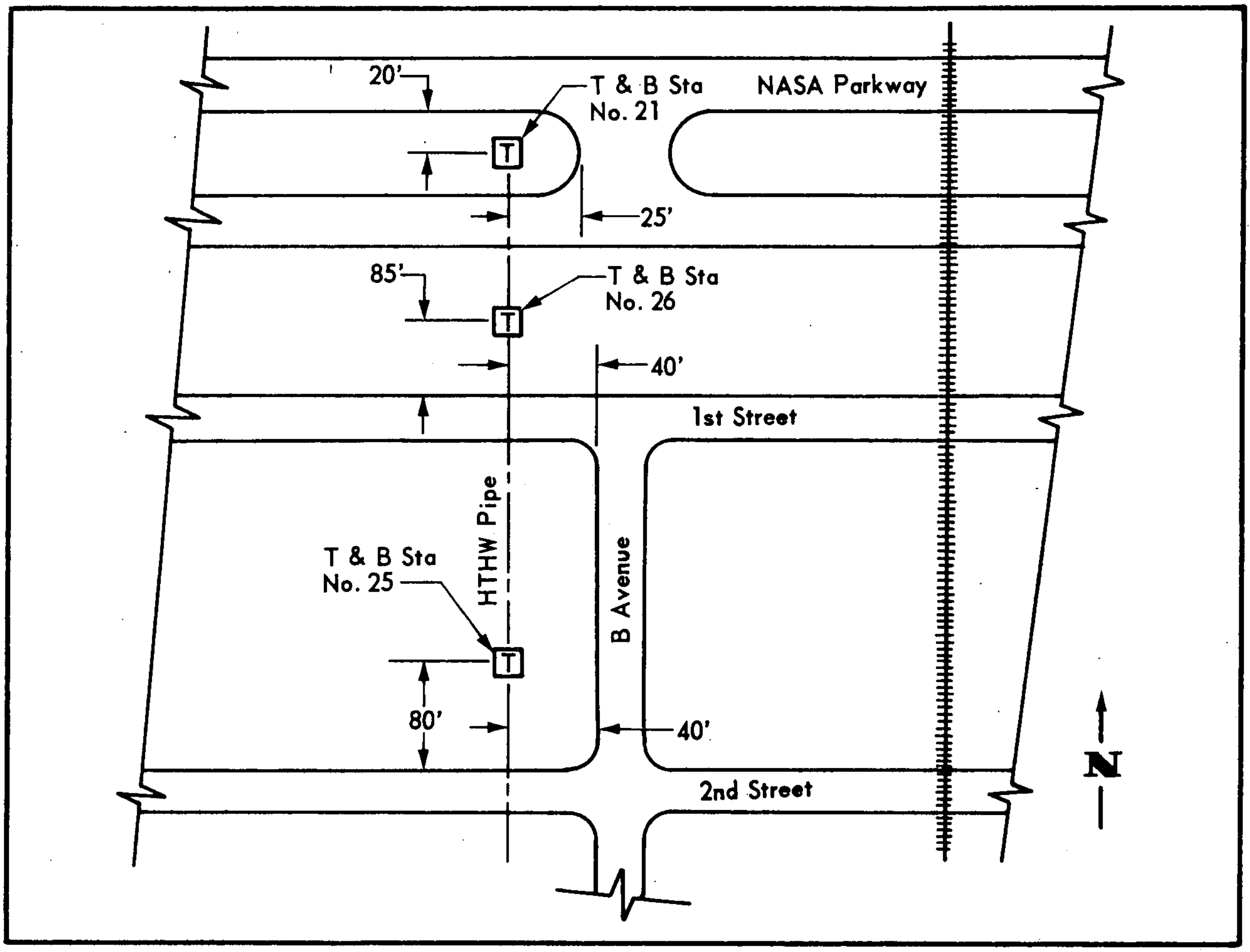


Figure 1-45. Test and Bond Stations No. 21, 25, and 26 Equipment Locator

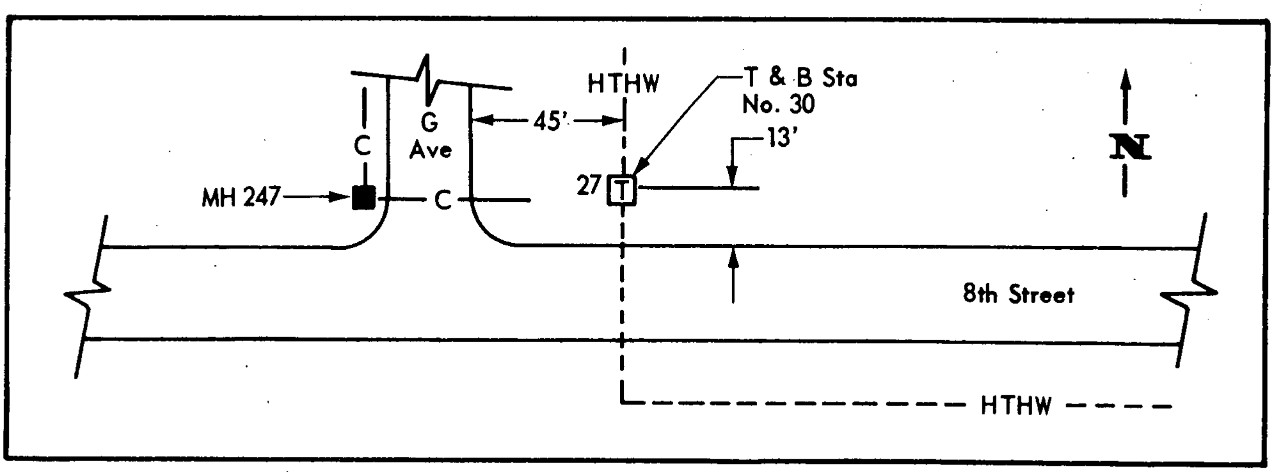


Figure 1-46. Test and Bond Station No. 30 Equipment Locator

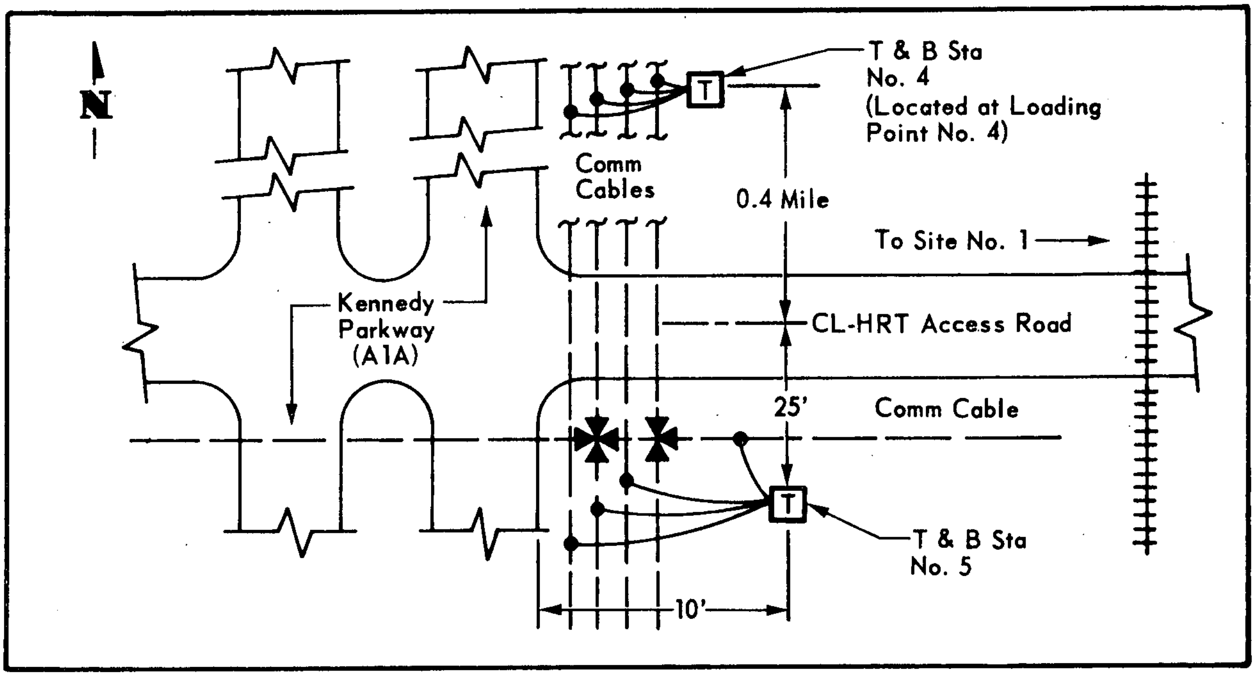


Figure 1-47. Test and Bond Stations No. 4 and 5 Equipment Locator

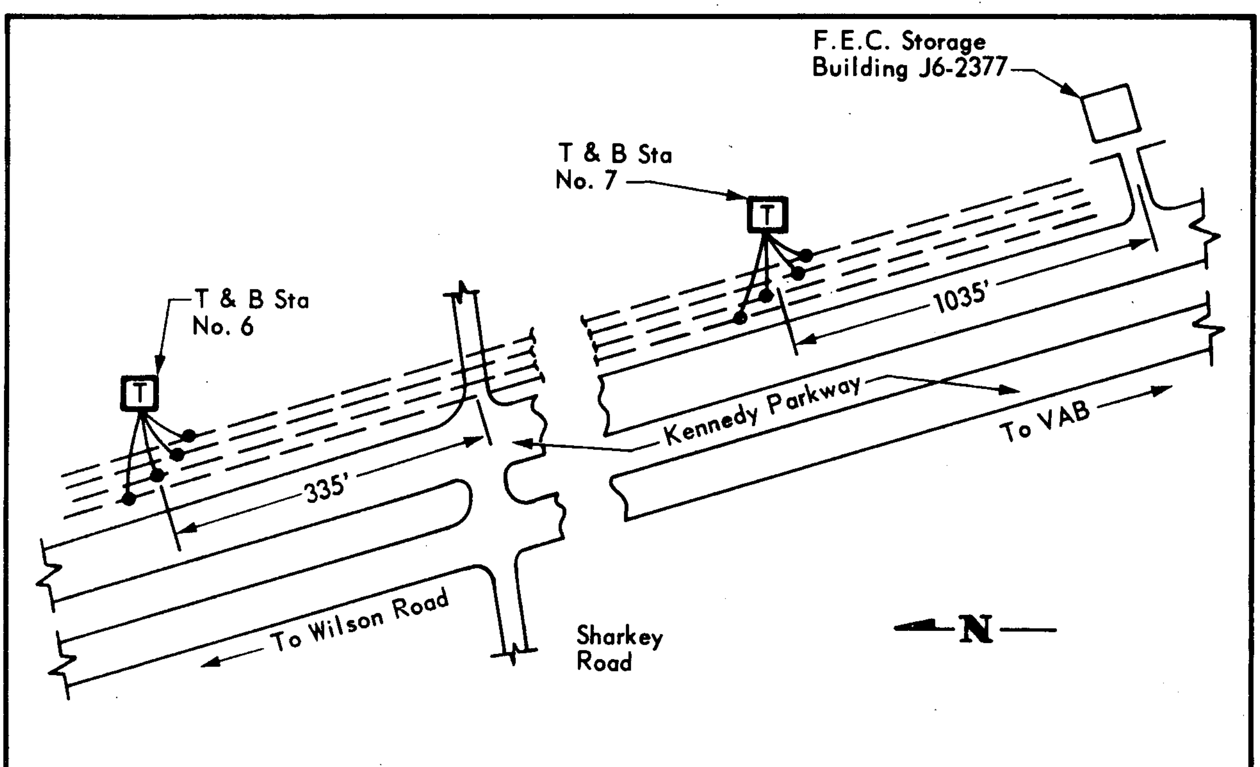


Figure 1-48. Test and Bond Stations No. 6 and 7 Equipment Locator

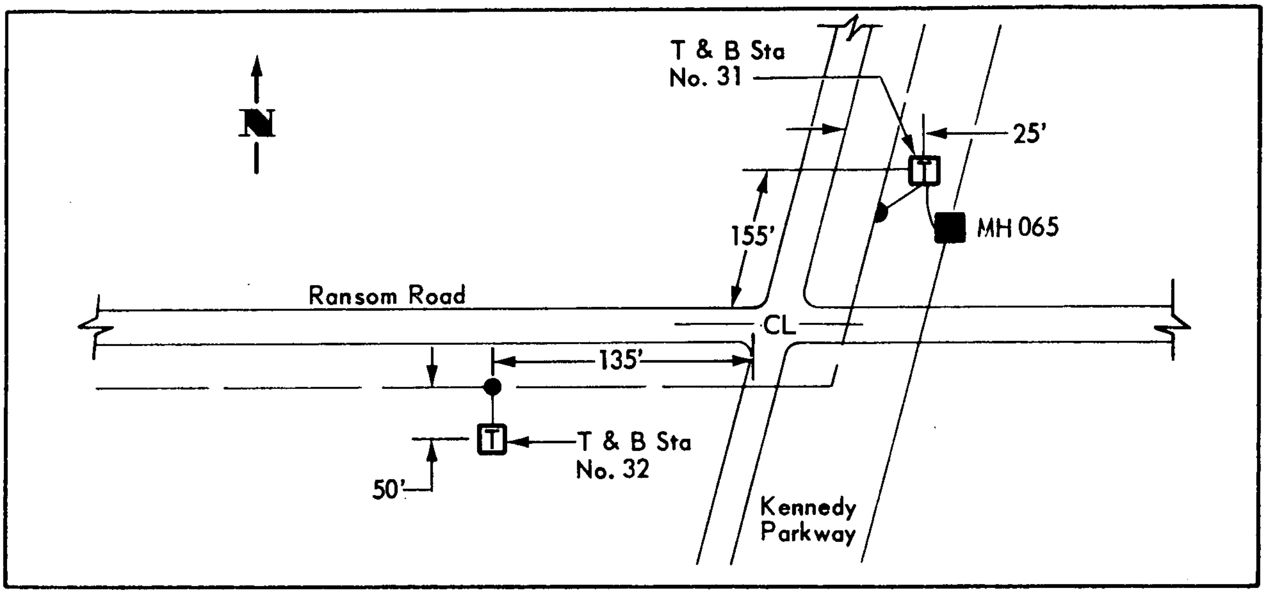


Figure 1-49. Test and Bond Station No. 31 and 32 Equipment Locator

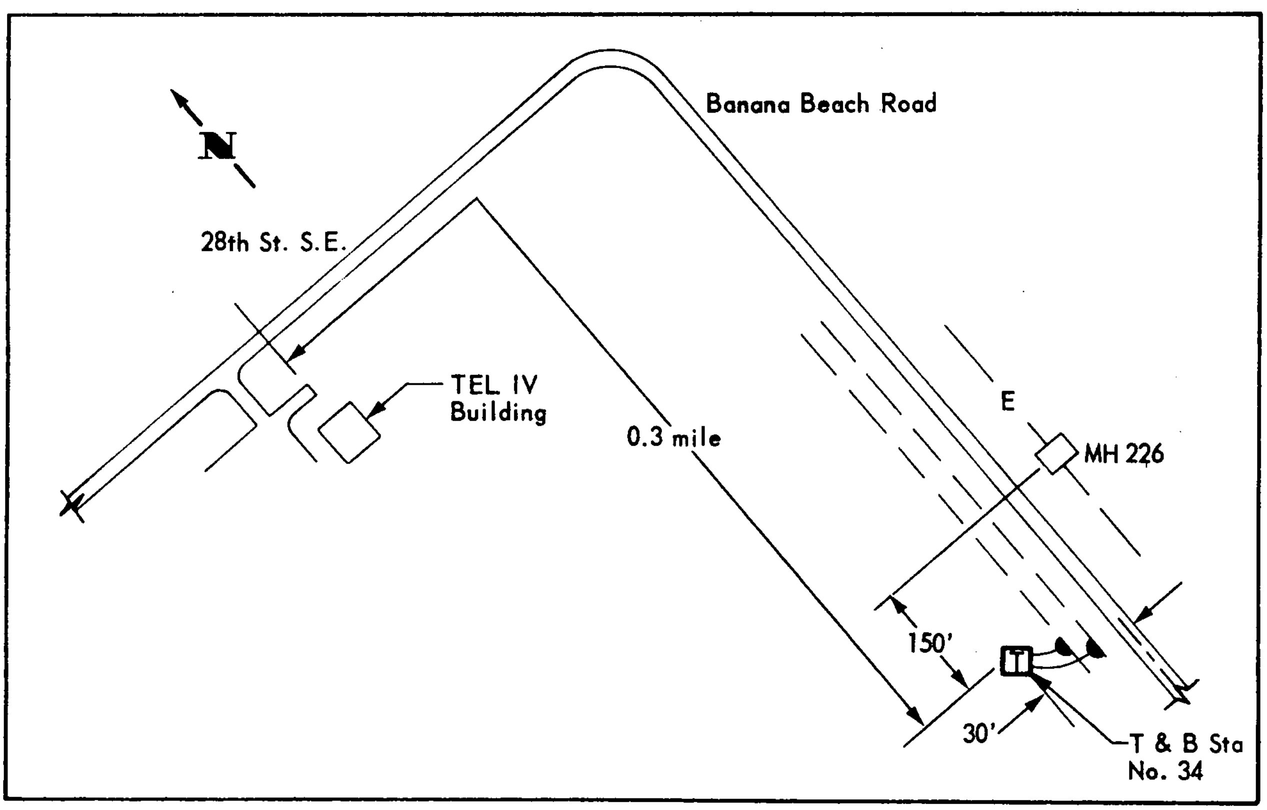


Figure 1-50. Test and Bond Station No. 34 Equipment Locator

SECTION II
THEORY OF OPERATION

2.1 GENERAL

This section contains objective theory and a functional description of a typical cathodic protection system of the type used to protect communication cables at KSC. The functions described in Paragraph 2.3 are based on the assumption that power is applied and operating controls are positioned in accordance with preoperation procedures contained in Section III of this manual. (See Figure 2-1 for schematic details.)

2.2 OBJECTIVE THEORY

Corrosion, as applied to communication cabling, is deterioration of the metal sheath primarily due to two corrosive forces; the first is an electro-chemical process (galvanic cell) in which the anodic material is absorbed or combines with an electrolyte and is transferred through flow of electric current to the cathodic element of the electro-chemical cell. The metal sheath of communication cable buried in moist conductive soil or submerged in water is polarized by this electro-chemical action and forms the anode of an electrical cell that supports the transfer of sheath material to dissimilar metal particles in the soil. The second electrical force is generated by the junction of dissimilar metals, supporting hardware, etc., with the cable sheath forming a thermocouple and resultant current flow. Current flow in such a cell or junction of dissimilar metals and the resulting corrosion of the cable sheath is dependent on the elements of the cell or junction; the brackish or salty moisture and the composition of local soil is ideal for either electro-chemical process and cables, unless protected, will fail due to corrosion in a short period of time. To arrest this flow of current and resulting corrosion, the cathodic protection system imposes an electrical field in the area of the cable that is of the opposite polarity of the electro-chemical cell which neutralizes action of the cell and the electro-chemical action on the cable wheath is stopped. To assure that such a system is performing its design intent, test instruments are used to measure the potential and polarity of the resultant fields and a reading of -0.85 volts, as read on a potentiometer, is considered an optimum indication that the cable sheath is not the anodic element of the field and, therefore, is not being erroded.

2.3 CATHODIC PROTECTION SYSTEM (TYPICAL)

The cathodic protection system is manually energized and operates continuously until shutdown for maintenance or emergency reasons. The forty segmented systems forming the overall system must be tested periodically to maintain an adjusted and balanced system. These tests consist of taking measurements at the various stations throughout the system using a potentiometer-voltmeter and a copper-copper sulfate half cell to determine the polarity and the voltage potential difference between the underground cable sheath and the surrounding soil. The resulting data tabulated from measurements taken at each station indicates the amount of Cathodic protection the communication cables are receiving. To assure accuracy of tabulated data, these data may be compared with Table 7-1 Initial System Balance Records taken at time of installation of the Cathodic Protection System for Communication Cables, KSC. As stated in Objective Theory, Paragraph 2. 2 above, an optimum or standard potential which determines that enough direct current is flowing to the cable sheath to provide corrosion control is -0. 85 volt. Although this standard value should be used as a reference throughout the Cathodic Protection System, readings of a lesser value do not necessarily mean that Cathodic protection is not present. Variances in soil conditions, moisture and the presence of metals (other than steel) in certain areas will cause readings to be less than the standard of -0. 85 volt. Other methods to detect a change in voltage potential is to tabulate readings with the rectifiers on and off. These differences in readings will show the affect of the Cathodic Protection System and also show the affect of polarization on the cable sheath. After shutdown, slow or gradual decrease in voltage potential indicates good polarization. Theory of operation of a typical segment or site of the overall system starts with flow of current from the 120 vac, single phase, 60 cycle power source through a fused disconnect switch (Figures 1-2 through 1-40) to input terminals of the rectifier unit (Figure 2-1).

2. 3. 1 RECTIFIER UNIT. The rectifier unit is manually started and operates continuously until manually shutdown. The path of current flow in this unit is through the primary power circuit breaker, stepdown transformer and into the selenium stack of the rectifier. This input circuit is protected by a lightning arrestor. The transformer reduces line voltage from 120 vac to values shown on the Schedule of Sites to accommodate power requirements for the various site locations and each transformer is equipped with voltage adjustment taps. Current leaving the rectifier flows through the following dc components: filter choke which is used to dampen communication interferences; fuse for overload protection; meter for voltage and amperage readout; meter switch; this circuit is also protected by a lightning arrestor. Rectifier units with two positive terminals serving two strings of anodes are equipped with a variable resistor (Figure 2-1) for individual circuit adjustment and has two meter switches for connecting the meter to each individual circuit.

2. 3. 2 ANODE BED. The anodes connect to the positive terminal(s) of the rectifier through the anode leads and header cable. The negative

terminal of the rectifier connects to the protected structure or cable sheath and the impressed current loop is completed through the conductive soil.

2.3.3 TEST AND BOND STATIONS. Test leads have been installed at thirty-four locations through the Cathodic Protection System as listed on the Schedule of Sites. Potentiometer readings made at these station leads are compared to test results taken at installation to indicate the efficiency of the system. (See Figures 1-4, 1-6, 1-7, 1-12, 1-13, 1-14, 1-28, 1-30 through 1-32, 1-37 and 1-41 through 1-50.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

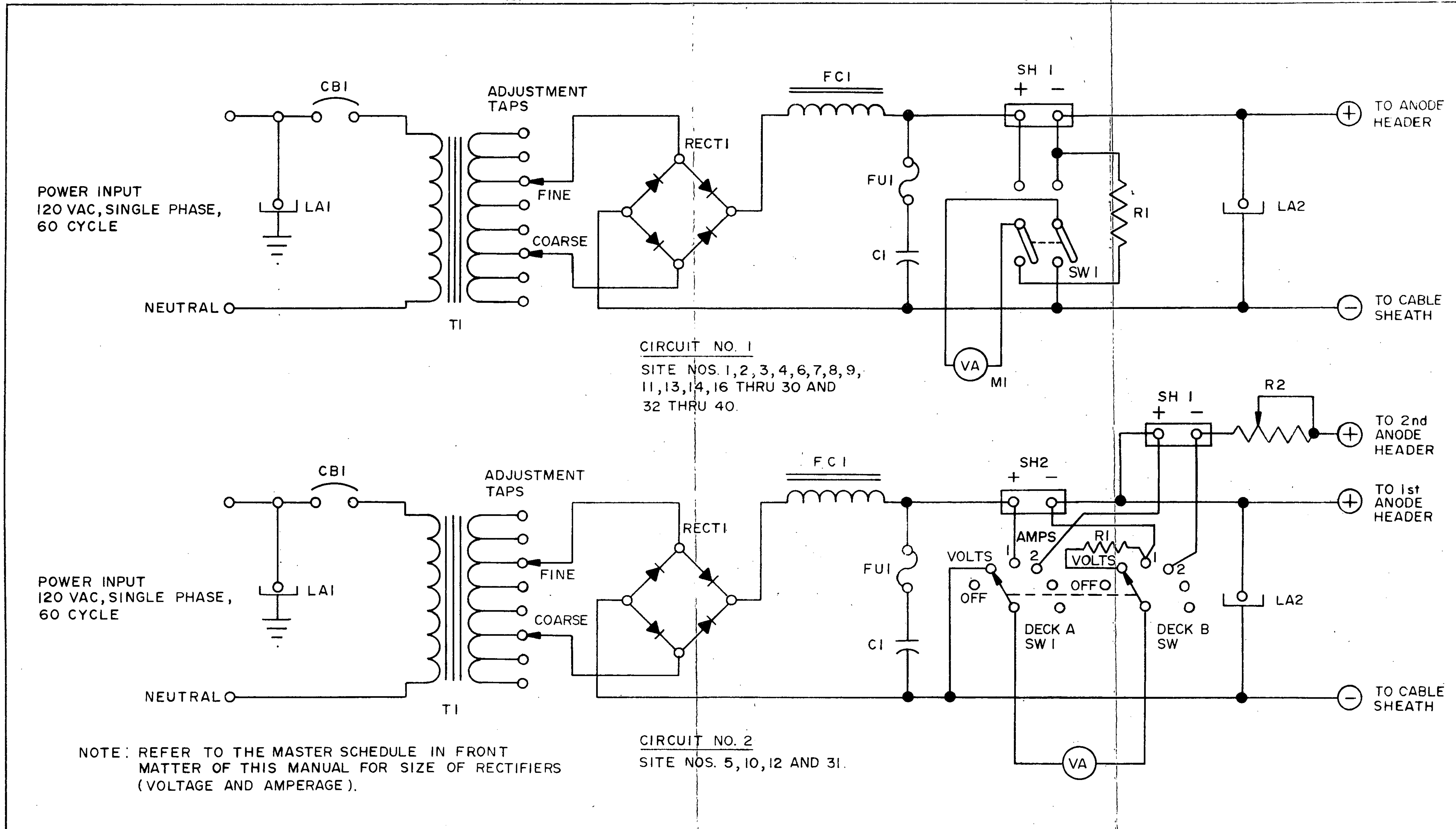


Figure 2-1. Cathodic Protection System Rectifier Schematics

C2

SECTION III
OPERATION

3.1 GENERAL

This section contains operating instructions for the Cathodic Protection System for Communication Cables, KSC, including routine safety precautions, preoperation and startup procedure, during operation procedure and shutdown procedure. A reference is made to system balance instructions appearing in Section VII when test readings are substantially changed and adjustments are necessary. When components malfunction during operation, notify the shift supervisor and the cognizant maintenance support agency. Refer to appropriate troubleshooting steps in Section VI, Table 6-1 and restore system to normal operating condition. (See Figure 3-1 for a typical system control panel.)

3.2 SAFETY PRECAUTIONS

Operating personnel assigned to Cathodic protection systems are required to observe the following general safety precautions:

a. Consider electrical circuits energized until verified deenergized.

b. Use insulated gloves and boots when operating electrical equipment in damp or wet locations.

c. Restrict nonessential personnel from the immediate areas where electrical equipment is operated, monitored or maintained.

d. Operate switches in a quick, positive manner to minimize arcing.

Note

In addition to the preceding safety practices, the requirements of the Kennedy Management Instruction KMI 1710 KSC Safety Program applies to operation and maintenance of this equipment. Refer to Section V for safety precautions relating to maintenance procedures.

3.3 PREOPERATION AND STARTUP PROCEDURE

CAUTION

When a selenium rectifier is new or has been shutdown for periods longer than 24 hours, the selenium cells may deform. To reform the selenium plates without damage, perform the following steps of procedure.

a. Close disconnect switch and when applicable, verify that upstream circuit breaker is positioned to ON. (Circuit breaker locations are shown on equipment locators, Figures 1-2 through 1-40.)

b. Note or identify COURSE ADJUSTMENT tap for normal operation. (Position of adjusting strap.)

c. Position course adjustment strap to lowest voltage position. (See Figure 3-1.)

d. Position panel circuit breaker to ON and operate unit for 2 minutes.

e. Position course adjustment tap to next higher tap and operate unit as in step d.

f. Repeat step e procedure until normal position tap, as identified in step b, is reached.

3.4 DURING OPERATION PROCEDURE

During operation procedures are limited to verifying and recording meter readings and comparing these readings to those shown in Initial System Balance Records (Table 7-1), which were taken during original system balancing and adjustment. This procedure should be performed at least every 30 days. Meter readings will vary with changes in resistivity of the soil and other material through which rectifier current flows; i.e., readings will increase in wet weather and decrease during dry weather. Therefore, satisfactory system operation should be based on Test Station readings, as described in system balancing and checkout procedures in Section VII, and rectifier meter readings (Table 7-1) used only to verify that the unit is operational and not operating beyond its maximum capacity. When it is necessary to change rectifier output, the coarse and/or fine adjustment taps are moved accordingly. The coarse taps are connected at one-fifth increments of the transformer secondary and the fine taps further divide this increment. For example, on a 60-volt rectifier, each coarse tap changes the input voltage to the rectifier by 8 volts and each fine tap by 1.6 volts. It should be remembered that the rectifier connects into a very low impedance load and changes in tap adjustments result in considerable current change, with little change in voltage as monitored on the rectifier meter.

3.5 SHUTDOWN PROCEDURES

This system is deenergized only for maintenance, checkout and system balancing. To deenergize for maintenance, position panel circuit breaker to OFF and open disconnect switch. To deenergize for checkout or system tests, refer to procedures in Section VII.

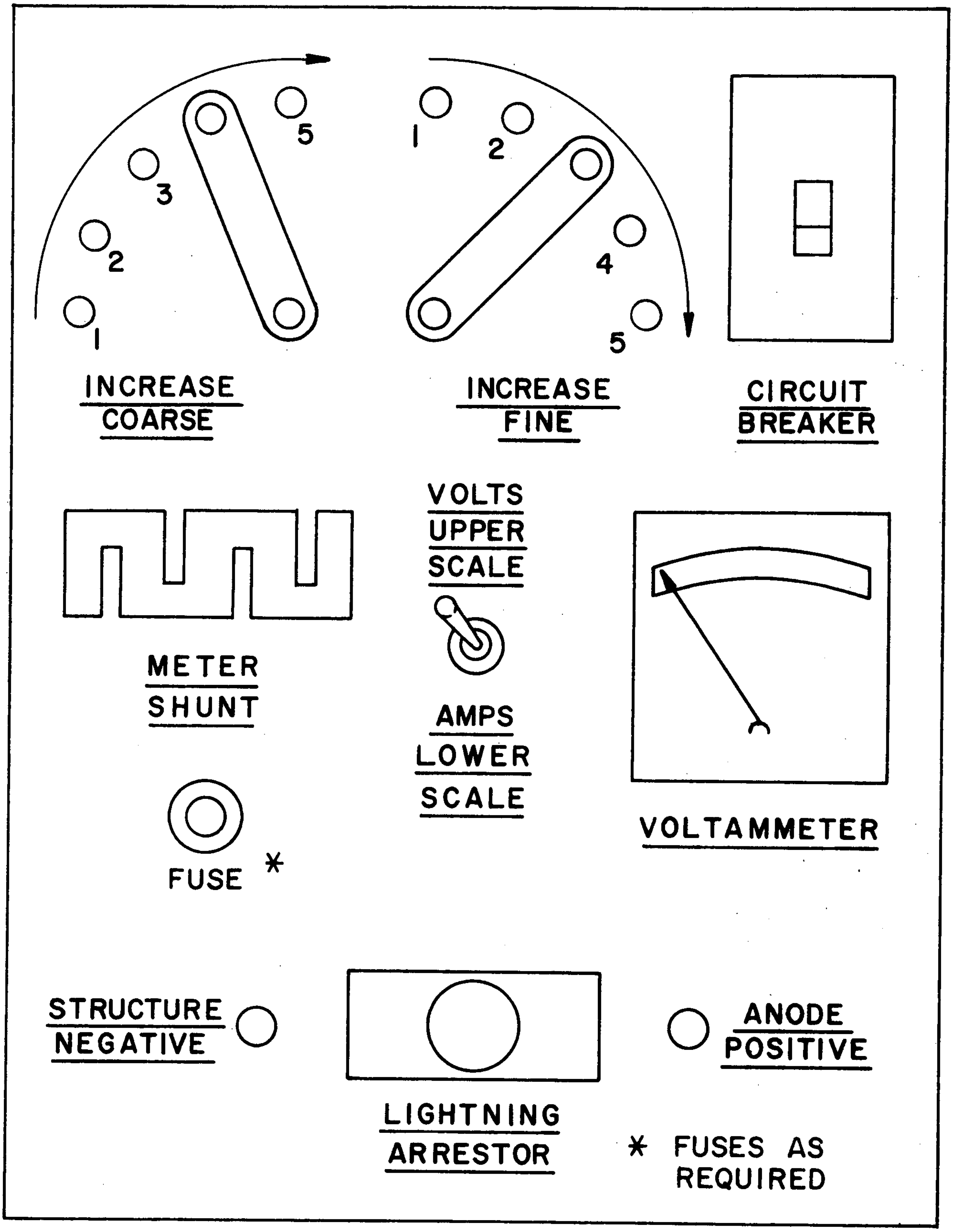


Figure 3-1. Rectifier Control Panel (Typical)

SECTION IV
SPECIAL TOOLS AND TEST EQUIPMENT

4.1 GENERAL

Special tools and test equipment required to operate and maintain components of the Cathodic Protection System for Communication Cables is limited to the following test instrument:

Multicombination Meter Models B-3, M-3 Scale: 1 mv to 20 volts M. C. Miller Instrument Company (or equal)	1 req
Half-Cell, Copper/Copper Sulfate M. C. Miller Instrument Company (or equal)	1 req
Test Lead Stranded Copper, Insulated	2 req

SECTION V
PREVENTIVE MAINTENANCE

5.1 GENERAL

This section contains preventive maintenance instructions for the Cathodic Protection Systems to include safety precautions, periodic inspections and service procedures, lubrication, alignment, calibration, adjustment, cleaning, corrosion control and painting. (Refer to Section VI Troubleshooting Procedures when routine inspections reveal impending trouble.)

5.2 SAFETY PRECAUTIONS

Maintenance personnel assigned to inspect, service or repair components of the Cathodic Protection System are required to observe the safety practices of the Kennedy Management Instruction KMI-1710 KSC Safety Program and the following general precautions.

a. Do not rely entirely upon safety devices to prevent accidents.

b. Verify that power disconnect switch is OFF prior to starting work on equipment that is electrically controlled or actuated. Tag and lock switch in OPEN position.

c. Ensure that at least two men work together in all cases where work is performed on or near live conductors.

d. Use insulated gloves, boots and tools to prevent electric shock from live circuits while working in damp or wet locations.

e. Ensure that at least two men are present in all cases where work is performed in manholes.

f. When work is completed, make certain electrical boxes, switch covers and panels are replaced with appropriate attaching parts prior to restoring power.

5.3 PERIODIC INSPECTION AND SERVICING

Periodic inspections and servicing of the Cathodic Protection System shall be scheduled and performed in accordance with instructions contained in Table 5-1.

5.4 LUBRICATION

Lubrication of this system is limited to the following procedure:

a. Fill tanks of oil immersed, explosion proof rectifiers at Site Nos. 10, 32 and 36 with an approved silicone lubricant conforming to Spec. VV-I-530 No. 2. An oil level gauge is provided on outside panel of the enclosure to indicate when tank is full.

CAUTION

When performing the following procedure, use care to prevent oil from contacting electrical components or wire insulation.

b. Apply a light coat of oil to hinges of the rectifier enclosures. Use SAE 20 or 30 weight oil conforming to Specification FED-VU-526, or approved equivalent.

5.5 ALIGNMENT, CALIBRATION AND ADJUSTMENT

5.5.1 ALIGNMENT. There are no alignment procedures required for the Cathodic Protection Systems.

5.5.2 CALIBRATION. Calibration of the Cathodic Protection Systems is limited to verifying the accuracy of meter installed on the rectifier control panel. A single-point check may be made by substituting a portable instrument of known accuracy and comparing voltage and current readings, or at 3 month intervals, the meter should be calibrated at a calibration laboratory. Accuracy of the meter shall be within plus or minus 2 percent of full scale deflection.

Note

Dirty or burned contacts in meter switches will cause erroneous readings. To avoid error, repeat accuracy measurements until 4 identical consecutive readings are obtained.

5.5.3 ADJUSTMENT. Adjustment of the Cathodic Protection System shall be performed in accordance with the system balance procedures contained in Section VII of this manual.

5.6 CLEANING AND CORROSION CONTROL

5.6.1 CLEANING

WARNING

Do not use solvents having a flash point lower than 400° F. Cloths and cotton waste used in cleaning procedure are to be placed in closed metal containers or destroyed to prevent fire.

All metal surfaces (galvanized surfaces excluded) are to be cleaned before applying paint. Remove oil, grease, dirt, loose rust, loose mill scale and other foreign material to the extent that all surfaces meet the requirements of SSPC Specification SP 7. Blast cleaning is permitted to remove stubborn deposits of residual rust provided that electrical components within the enclosure(s) are not exposed to sandblast materials.

5.6.2 CORROSION CONTROL. Prime coat the interior and exterior surfaces of metal enclosures (galvanized surfaces excluded) with paint conforming to Federal Specifications TT-P-57, Type 1; TT-P-86, Type 1 or 11; TT-P-615, Type 1, 11 or V; TT-P-645; or an approved rust inhibitive paint provided by the manufacturer of the item and equal to the above specified materials. Apply primer coat by brush as soon as practicable after cleaning and preparation of metal surfaces of completed. Apply paint under dry, dust-free conditions at temperatures above 40° F. Dry film thickness of each coat of paint is required to be 2.0 mils. All prime coated ferrous metal in exposed locations shall be given two finish coats of aluminum paint conforming to Federal Specification TT-P-38, or equal. Prime coated ferrous metal in exposed-to-view locations shall be given a coat of interior enamel undercoat conforming to Federal Specification TT-E-545a and AM-2 followed by a coat of semigloss interior enamel in a color to match with existing adjacent painted surfaces and conforming to Federal Specification TT-E-509b.

Table 5-1. Periodic Inspection and Servicing (Sheet 1 of 4)

ITEM	FREQUENCY	INSPECTION/MAINTENANCE
		Note Each segment of the overall Cathodic Protection System protects a section of communications cable against corrosion. It is therefore important that current and voltage output of each rectifier be checked periodically to assure total balance of the system and provide optimum protection against corrosion of the cable sheath material.
Rectifiers	Monthly	Measure current and voltage output of the rectifiers. Repeat measurements four (4) times on each meter to assure that switches are contacting properly. Record readings and compare these readings with those taken during the last inspection and against the initial readings taken during balance procedures when equipment was installed. (Refer to Section VII) Any significant change would point to failure of a system component. In this event, refer to Section VI Troubleshooting Procedures.
Rectifier Components		Rectifier Stack Temperature. Deenergize the rectifier and feel the stacks to make certain they are operating properly. The stacks should be warm. If one stack is cold, the unit is operating as a half-wave rectifier. This condition if allowed to continue, would result in failure of the unit as half of the stacks would be carrying the full current load. Interference problems is also a symptom of half-wave operation. Replace cold stack(s) and recheck to assure rectifier is operating properly.

Table 5-1. Periodic Inspection and Servicing (Sheet 2 of 4)

ITEM	FREQUENCY	INSPECTION/MAINTENANCE
Rectifier Components (continued)		Rectifier Cleanliness. Maintain cleanliness of the rectifier components to assure proper cooling as service life of the unit is dependent on proper heat transfer. Any accumulation of dirt or other foreign material will cause stacks to overheat resulting in premature failure. Make sure stacks are clean and well ventilated.
	Monthly	Contact Temperatures and Arcing. A loose connection is a high resistance connection that overheats and oxidizes to the point of failure. When unit is turned off, feel all electrical connections for warm or hot connections which may result in failure. Disconnect, clean and re-tighten faulty joints. Check components for arcing caused by lightning surges, water entering the unit, breakdown of insulation or other forms of short circuiting. Clean and repair, as required.
	90 Days	Meters. Check meters in each rectifier for accuracy against a known standard by measuring across the output terminals and compare this reading with that of the unit meter. Current output can be measured by connecting across the built-in shunt. Inspect meters for broken glass, damaged leads, loose connections, dirt or corrosion. Clean and repair, as required. Check pointer for zero adjustment. Tap case lightly and set pointer to zero, if required. Replace meters found to be out of calibration and send defective instrument(s) to the appropriate repair facility for recalibration.

Table 5-1. Periodic Inspection and Servicing (Sheet 3 of 4)

ITEM	FREQUENCY	INSPECTION/MAINTENANCE
Rectifiers-Explosion Proof Units	Monthly	In addition to the procedures outlined above, check oil level in sight glass on side panel of each explosion proof unit. Add oil conforming to that specified in Paragraph 5.4. Check tanks for leakage at fittings or gasketing.
Disconnect Switches		Inspect for dirty or burned contacts. Clean or repair, as required. Check fuses for continuity, contact cleanliness and security of connection.
Circuit Breakers		Check operating mechanism to make sure it operates freely, yet is positive in closing, latching and tripping. Check security of wire connections and attaching parts.
Transformers		Inspect transformers for rated or adjusted load control. Clean and tighten adjustment taps and maintain transformers in a clean, dry condition.
Terminal Blocks		Inspect terminal blocks for cracks, breakage, dirt and loose wire connections. Tighten loose screws, lugs and mounting bolts. Clean board and dirty or corroded terminal connections with brush and cloth moistened with cleaning solvent. Dry with clean, dry air or nitrogen. **Note** Use a low toxicity cleaning solvent, Code 98-1, or equivalent.
Wiring		Inspect wiring for security of connections and burned or frayed insulation. Replace defective wiring, as required.

Table 5-1. Periodic Inspection and Servicing (Sheet 4 of 4)

ITEM	FREQUENCY	INSPECTION/MAINTENANCE
Anodes	As necessary	Any substantial change in readings may denote anode deterioration. (Refer to Equipment Locators in Section I; isolate anode bed (concrete markers); and repair or replace defective anode(s).

SECTION VI
TROUBLESHOOTING PROCEDURES

6.1 GENERAL

This section contains troubleshooting procedures for the Cathodic Protection System. When trouble occurs, refer to the appropriate troubleshooting step in Table 6-1. All possible action should be taken to maintain an operational system although continued operation is at reduced efficiency. When shutdown is imperative or occurs inadvertently, the operator must notify the shift supervisor immediately. (Refer to Figure 6-1 Cathodic Protection System Wiring Diagram.)

6.2 CATHODIC PROTECTION SYSTEM FOR COMMUNICATION CABLE (TYPICAL)

Troubleshoot the Cathodic Protection System in accordance with procedures contained in Table 6-1.

Table 6-1. Troubleshooting Procedures (Sheet 1 of 2)

STEP	TROUBLE	PROBABLE CAUSE	REMEDY
1	No rectifier input	Loss of primary power	Check and restore power
		Disconnect switch open or blown fuse	Close switch or replace fuse, as required
		Circuit breaker tripped or defective	Reset, repair or replace breaker, as required
		Loose connection at stacks, adjustment taps or defective transformer	Tighten connection(s) or replace transformer, as required
2	No rectifier output	Refer to step 1	Refer to step 1
		Note If breaker trips due to a steady overload, reduce output slightly. If breaker trips repeatedly even with output reduced, trouble may be; short circuit (line to line or line to ground) in some component. Isolate component, then check insulation with ohmmeter or megger. If breaker trips occasionally for no obvious reason, trouble may be; temporary overload due to soil moisture changes; line voltage surges; intermittent short circuit; or thermal radiation.	
		Rectifier stack(s) defective	Replace stack(s)
		Filter-Choke defective	Replace filter-choke
		Switch defective	Replace switch

Table 6-1. Troubleshooting Procedures (Sheet 2 of 2)

STEP	TROUBLE	PROBABLE CAUSE	REMEDY
2 (cont)	No rectifier output (cont)	Resistor defective	Replace resistor
		Meter/shunt defective	Replace meter or shunt
3	DC output voltage obtainable at rated dc current is only half what it should be	Half of stacks open-circuited causing unit to operate as a half-wave rectifier	Repair or replace stacks, as required
		Low line voltage	Restore normal voltage
4	Interference noise in communication line	Capacitor fuse blown	Replace fuse
		Capacitor defective	Replace capacitor
		Choke overheating due to overload or short circuit	Isolate defective component and repair or replace
5	Voltage read at test and bond station is low or of incorrect polarity	Loss of anode field or connection to field	Replace lead to field or replace anode field

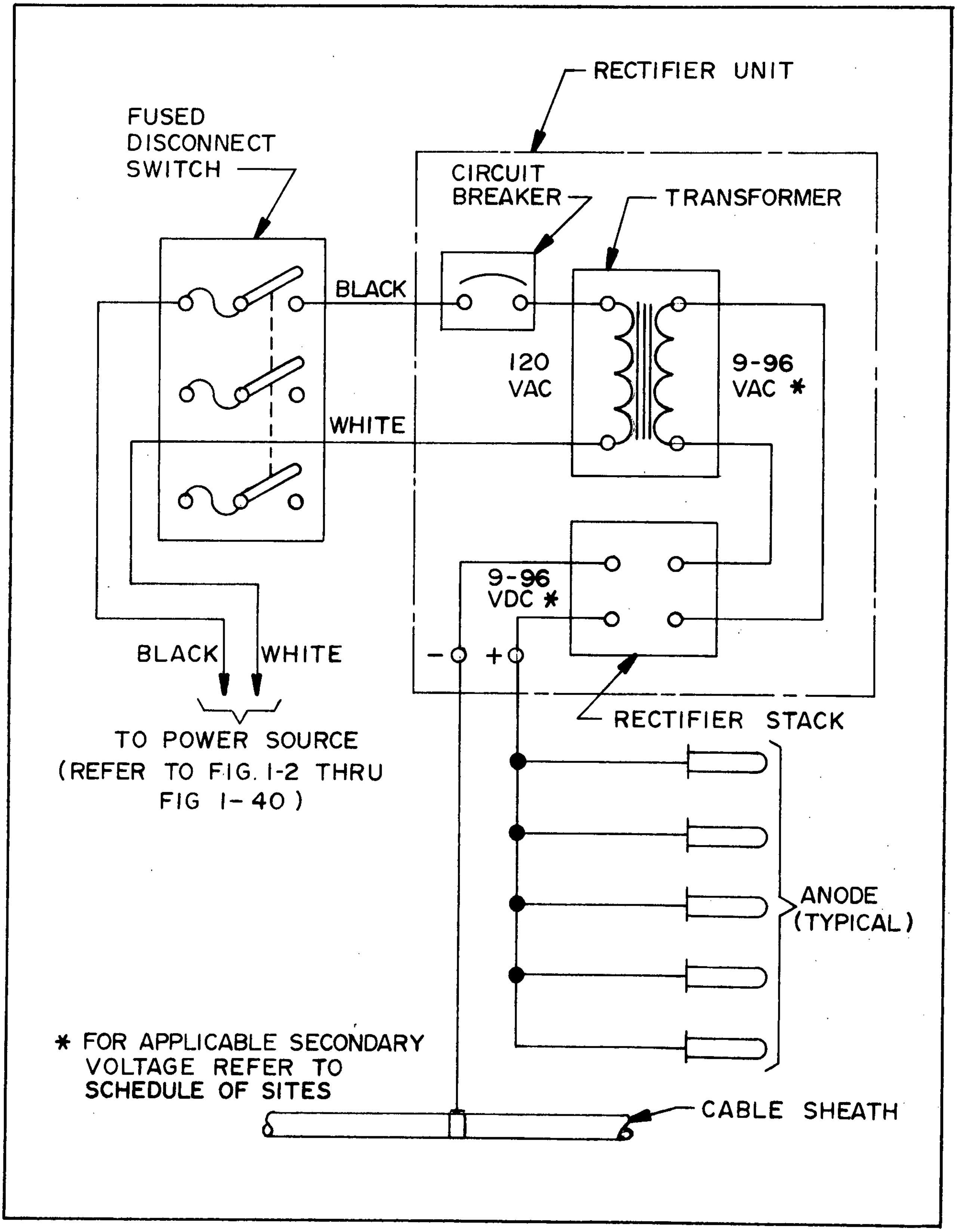


Figure 6-1. Cathodic Protection System Wiring Diagram

SECTION VII
CHECKOUT PROCEDURES

7.1 GENERAL

This section contains checkout and system balancing procedures for components of the Cathodic Protection System and the initial system balance records prepared after installation of each of the thirty-nine segments comprising the overall system. To facilitate system balancing of the overall system, test stations are provided at strategic locations along the cable run to assure that communication cables are receiving adequate protection against corrosion. (Refer to the Test Station Equipment Locators in Section I.)

7.2 COMPONENT CHECKOUT

7.2.1 LIGHTNING ARRESTORS. High voltage surges from lightning are the greatest hazard for selenium rectifiers used for cathodic protection. It is, therefore, very important the rectifier case be properly grounded. Checkout the arrestors, their ground connections and make certain the fused disconnect switch ahead of the ac arrestor and the circuit breaker downstream are functional and armed.

7.2.2 TRANSFORMERS. Checkout the transformer after repair or replacement procedures are completed. Make certain connections are secure and the voltage taps are positioned to the same taps used prior to replacement. If ac line voltage is applied to the primary of the transformer but is not measurable at the secondary taps, check to determine if there is an audible hum coming from the transformer. If so, the primary is operating but the secondary is probably open. If there is no hum, the primary is probably open. To isolate the trouble, disconnect the transformer and check dc resistances of the windings with an ohmmeter. Primary should have 1 to 10 ohms resistance and secondary should read 1 ohm or less. If either resistance measurement is high, the particular winding is open and the transformer should be replaced. Make sure the high resistance is in the winding and not across a bad connection.

7.2.3 RECTIFIERS. Checkout the rectifiers after repair by energizing the unit for a short interval (15 minutes) to allow warmup and temperature to stabilize. Check and make certain the rectifier stacks are all warm to the touch. Next, feel each electrical component and connection for hot spots which would denote a high resistance connection. Clean and tighten, as required. When a unit is adjusted to near maximum output, future changes such as ground bed resistance due to rainfall or line voltage changes should be considered as these conditions could vary the output of the rectifier. It is not advisable to allow the rectifier to operate over 10 percent above the maximum rated voltage as damage to the unit may result. The meter on the rectifier panel should be checked prior to placing the rectifier into service. Perform meter check in accordance with Paragraph 5. 5. 2.

7. 3 SYSTEM BALANCING

7. 3. 1 INTRODUCTION. This system provides Cathodic Protection for an extended network of cables throughout the NASA Merritt Island Facility. Rectifier units and anode beds are installed at various intervals along these cables according to requirements. System balancing consists of adjusting the output of these several rectifier units so as to maintain optimum protection for these cable runs. The output current requirement for each rectifier is determined by checking the polarity and voltage potential between the cable sheath and the surrounding soil. These measurements are made using a meter and copper/copper-sulfate half cell as listed in Section IV. This is a combination meter that measures low potential current and measures voltage potential, either directly or compared to the half cell. A typical test set-up is shown in Figure 7-1, however, this meter and test equipment should be used in accordance with vendors instruction manual for the application desired. Test stations are located throughout the system, as shown in equipment locators in Section I, and contain test lead terminals connected to the underground cable sheath and other foreign structures, such as piping systems, that may be adjacent to the cable runs. These test stations only supplement available and necessary test points. Test valves, pressure alarm stations and other cable hardware, extending above grade from the cable sheath may be used to determine the soil/sheath potential at that point. Current in an electrical system flows the path of least resistance and the 40 volt 16 amp output of a typical rectifier will flow to the cable sheath as shown in Figure 7-1. Therefore, a greater amount of current and a higher voltage potential will reach the cable immediately adjacent to the anode bed than will reach the cable at the outer limits of that unit and the theoretically correct soil/sheath meter reading of -0. 85 volt cannot be maintained at all points. In this system, two other system parameters must be used to establish an optimum balance in the system; first, <u>the maximum soil/sheath potential should not exceed -1. 2 volts</u> for a lead sheath cable and secondly, to assure minimum protection at locations with readings less than -0. 85 volt, generally found about half way between anode beds, a comparison of rectifier ON/OFF readings should be used. <u>A negative increase in potential of . 100 to . 150 volt in the test station reading, when the rectifier is turned from OFF to ON will indicate minimum protection.</u> For example, a soil/sheath reading of -. 480 volt, that increases to -. 580 to -. 630 will indicate adequate protection. Generally, the output of the nearest rectifier will be increased to bring an

intermediate test station reading within acceptable limits, however, between rectifiers there is an overlap of protection, or current flow, to the cable, and should test readings near the rectifier, in one direction, be at or near the maximum reading of -1.2 volts, perhaps the output of the rectifier in the opposite direction from the test point can be raised and the low reading corrected. The maximum potential of -1.2 volts is stated for lead sheath to soil relation; the maximum potential for cables with a steel outer binding or in ducts of other material should be made by an engineering determination. Generally the test station and other test point readings recorded during initial system balancing can be used as a guide for the optimum reading at any test point. The Cathodic Protection System is designed to protect the communication cables. However, some consideration must be given to foreign structures that are subjected to the current flow and voltage potentials of this system. Generally, these structures are piping systems and in some cases, test leads have been attached to these structures and terminated in the test stations (white wires) so the effect of cathodic current can be determined. Where some current flows from the anode bed to the structure and from the structure to the cable sheath, the structure remains a cathodic element of the circuit and corrosion is arrested, even though the protection afforded may not be as effective as that furnished the cables. One of the major reasons for establishing a maximum negative potential for the protected sheath or structure, is that a higher potential may establish a flow of current between that point and a point of lower potential on the same or adjacent sheath. If this current flow is established, the point of low potential becomes the anodic element and subject to corrosion. Isolated foreign structures within the field of the high potential cathodic element of this system may be even more adversely affected. For example, soil/sheath measurements, without cathodic current are -.420 volt, both adjacent to the anode bed and at a point several hundred feet distant along the cable. The rectifier is turned on and the output adjusted to increase the reading at the most distant point to -.580 volt; a soil/sheath reading is now taken at the cable adjacent to the anode bed and found to be -1.18 volts. This is satisfactory for cable protection, however, if we may assume there is a pipe system installed parallel to this cable, perhaps at a distance of 50 to 100 feet, it should be monitored. If the readings on the pipe system were approximately the same as the cable sheath, with the rectifier OFF, and the readings with the rectifier ON, changes greater than 0.05 volt, a jumper must be placed between the cable sheath and the pipe. For this reason, all known foreign unprotected structures, pipe system, building tanks, power installation, etc., within the field of this system, should be monitored.

The rectifier units may be adjusted from about one-fifth to full output and the only limitation is that they are not operated at voltage and amperage rates above the red-lined area on the unit meter face. On a typical 60 volt unit, the voltage can be adjusted from 12 to 60 volts in five steps, with the coarse adjustment taps; in each 12 volt range, there are five fine adjustments that will change the voltage in 2.4 volt steps. These adjustments are made only to achieve the desired soil/sheath readings and not to maintain specific readings on the rectifier meter. The only exception to this is that the unit should not be operated above its maximum (redlined) output. Ideally a rectifier would be adjusted during periods when the water concentration in the soil is at a maximum and for a 60 volt, 18 amp unit, let us assume that adjustment that satisfied soil/sheath measurements, is 40 volts at 10 amps. Let us assume that for 30 days there is little or no rain and the meter on the rectifier now reads 40 volts at 7.5 amps. This indicates that the drying of the soil has changed the total resistance of the current field from 4 to 5.3 ohms. The dryness of the soil also retards galvanic action (corrosion) and soil/sheath measurements may reflect that the reduced current output is adequate for protection. This may not always hold true and rectifiers cannot always be adjusted during ideal conditions. Therefore, system balancing procedures should be performed at least every 60 days and following any radical change in soil/water conditions.

7.3.2 SYSTEM BALANCING PROCEDURES. The Cathodic Protection System extends from its most Northerly point, Test Station No. 1 near Wilson Road and Kennedy Parkway to Site No. 40 near the Southern Facility boundary. Therefore, system balancing can be started at Test Station No. 1 and proceed numerically throughout the system and thus minimize backtracking necessary to verify adjacent Test Station readings, when rectifier adjustment is necessary. Only one test point or terminal is necessary for soil/sheath voltage tests. However, two test leads, one an AWG #12 and the other an AWG #8, are extended from each sheath test point and terminated in the Test Station. Generally, the #12 wires are bonded together and the terminals of the #8 wire used as a test point. White wires identify connections to foreign structures, however, more than one set of black wires (sheath connections) generally indicate connections to both sides of an insulated joint in the cable and terminals are tagged to indicate the direction of cable run from that test lead. It may be necessary to measure soil/sheath voltage at test stations and test points with one or more rectifier units in both the ON and OFF positions, and it may be one mile or more between some test points and the associated rectifier. Therefore, it is recommended that system balancing be performed by at least two technicians using adequate means of communication, such as two-way radios. Procedural steps for system balancing will assume that technicians have been positioned at the equipment for command-response type directions. The system should be balanced in accordance with the following procedures:

CAUTION

Test equipment recommended in Section IV for use in these procedures should be considered as laboratory instruments. It is not the purpose of this manual to provide guidance in its use. Equipment should be only used by technicians trained in its use and following manufacturer's instructions for its use as a voltmeter, semi-bridge using copper/copper half-cell as a standard, or as an ammeter, or serious instrument damage may result.

a. Starting test procedures at Test Station No. 1, refer to Figure 1-41, equipment locator, and verify that test meter is switched to the highest (20 volt) scale and connect meter and half-cell as shown in Figure 7-1 and in accordance with manufacturer's instructions to sheath test lead No. 1 (black). Half-cell should be held in an upright position as shown and dry grass or other foreign material removed so cell has good electrical contact with the soil. Only light hand pressure is necessary to accomplish this.

Note

For accurate readings, the half-cell should be placed over the cable to which the test station lead is attached.

b. Successively switch meter to each lower scale until a reading can be obtained. Reading should be within -0. 85 volt and -1. 2 volts or within ±5% of original test result indication. Record reading.

c. Repeat steps a and b for each test terminal at Test Station No. 1 and for each test point, as indicated on original test results, between test station and rectifier Site No. 1.

d. Press rectifier meter switch, at Site No. 1, to its upper (rectifier output voltage) position. Observe and record meter indication.

e. Press meter switch to its lower (rectifier output current) position. Observe and record meter indication. When released, switch will return to its center (off) position.

Note

Rectifier meter readings will vary with soil conditions. However, readings must not exceed red-lined area of dial scale.

f. Repeat steps a and b for each test station and test point, as indicated by original test results, between rectifier Site No. 1 and Site No. 2.

g. Repeat steps d and e at Site No. 2.

h. Repeat steps a and b at each test station and test point between Site No. 2 and Site No. 3.

Note

If all test station/test point indications and rectifier meter readings are within allowable limits, proceed to step k; if not, perform steps i or j, as required.

CAUTION

Rectifier adjustments shall not be made that increase the voltage reading at nearest test point to over -1. 2 volts or increase rectifier meter readings beyond red-lined area on meter dia.

i. If any test station/test point readings, taken north of Site No. 1 (rectifier) or south of Site No. 1 to a point approximately half way between Sites No. 1 and No. 2 are lower than allowable tolerances shown in step b, proceed as follows:

(1) Position circuit breaker on Site No. 1 rectifier to OFF and move FINE INCREASE adjustment bar to the next higher numbered position. Return circuit breaker to the ON position and repeat soil/sheath tests as necessary.

Note

At the start of this procedure, if FINE INCREASE bar is positioned at position 5, increase the COARSE INCREASE one step and move the FINE INCREASE bar to position No. 1.

(2) Repeat step i(1) as necessary until test point in question is within tolerance.

(3) Verify that all test station/test point and rectifier meter readings are within tolerance. It may be possible to decrease the rectifier at Site No. 2, one FINE INCREASE one step to accomplish desired readings. However, tests between Sites No. 2 and No. 3 must be repeated to verify this adjustment did not allow those test points to drop below tolerance.

Note

During dry soil conditions, there may be a general decrease in test station/test point readings, particularly near the edge of the electrical field (most remote test points). For any test points not within tolerance after performing steps (1) thru (3), perform step (4).

(4) Set up test equipment at out-of-tolerance test point(s) and record reading as shown in steps a and b. Position circuit breaker on associated rectifier to OFF. Observe test equipment. There should be a drop in reading, followed by further slow decrease in reading. After 30 minutes, record reading and turn circuit breaker ON. An increase of at least -.100 volt in reading should be considered acceptable and noted for future reference in dry soil conditions. If reading does not increase -.100

volt, is erratic or otherwise questionable, all readings should be subjected to an engineering evaluation and acceptable readings or corrective action for various soil conditions established.

j. Should test station/test point readings or rectifier output exceed allowable tolerances sequentially move rectifier adjustment bar to next lower position until desired readings are obtained. Observe all procedures and limitations described for increase adjustments in step i.

k. Repeat steps a, b, d and e for Sites 3, 4, 6 thru 9, 11, 13, 14, 16 thru 30, and 32 thru 40, and all associated test stations and test points. Refer to Equipment Locators in Section I and refer to original test results for optimum indications.

l. Repeat steps a and b for Sites 5, 10, and 31. Perform rectifier adjustments and output indications in accordance with steps m thru p.

m. Turn rectifier selector switch to VOLTS position (rectifier output voltage). Observe and record meter indication.

n. Turn selector switch to position 1. This is the total output current to both anode headers. Observe meter indication and record.

o. Turn selector switch to position 2. This is the current to anode header No. 2 only. Observe and record meter indication. Return meter to the OFF position.

p. RHEOSTAT R2 is located in the anode No. 2 circuit. Refer to Figure 2-1. Adjust as necessary to compensate for test station/test point indications affected by anode bed No. 2 current.

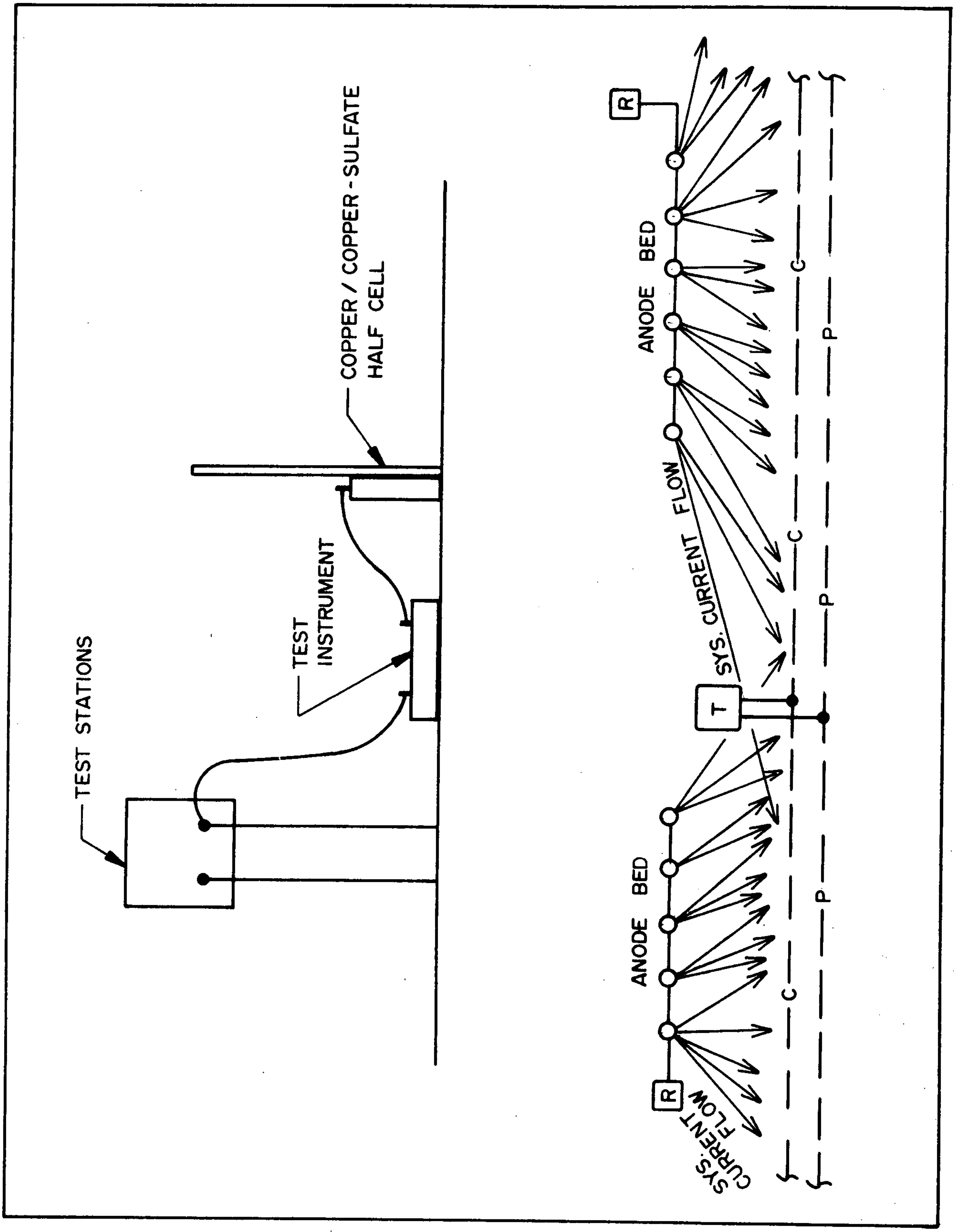


Figure 7-1. Rectifier Current Flow and Test Station (Typical)

Table 7-1. Initial System Balance Records (Sheet 1 of 19)

SITE #1 - Rectifier Output: 72.00V, 8.00A
High Resolution Tracking Station

Test Location	Readings	Comments
1	-0.55V	North cable, west side, insul joint
	-0.57V	North cable, east side, insul joint
	-0.62V	South cable, west side, insul joint
	-0.49V	South cable, east side, insul joint
2	-0.64V	MH 600, south side, insul joint
	-0.55V	MH 600, north side, insul joint
Site #1	-0.93V	At Rectifier
5	-0.89V	At Parkway and Hart Road
6	-0.78V	

SITE #2 - Rectifier Output: 11.00V, 11.00A
F.E.C. Storage Building (J6-2377)

Test Location	Readings	Comments
6	-0.78V	Happy Creek Road
Site #2	-1.10V	Terminal box, south side building
	-0.74V	Building at terminal box
	-0.68V	Guy anchor
	-1.10V	Pole ground rod
10	-0.98V	New test station at LUT Road

NOTE: A resistance bond was installed between the communications cable and building at the Terminal Cabinet, south side of the building. Measurements across bond were 1.45V, 1.2A, 1.2 ohm-centimeters.

Table 7-1. Initial System Balance Records (Sheet 2 of 19)

SITE #3 - Rectifier Output: 3.50V, 1.90A
Storage Building Area (North of LUT parking area)

Test Location	Readings	Comments
MH 409	-1.03V	
Bond Station 12	-0.97V	Comm cable (no connections to "Big 3" pipeline)
Site #3		
MH 411	-1.04V	High reading caused by LUT rectifiers
MH412	-1.09V	High reading caused by LUT rectifiers
18	-1.17V	High reading caused by LUT rectifiers
Comm. terminal cabinet 15J2 LUT #3 Park Site	-0.84V	

SITE #4 - Rectifier Output: 5.00V, 1.00A
Sewage Treatment Plant Building (K6-792)

Test Location	Readings	Comments
MH 409	-1.03V	
MH 407	-0.99V	
MH 407A	-1.03V	At Sewer Treatment Plant
Site #4	-0.74V	Plant piping
VIP Stands	-0.78V	Terminal Cabinet
MH 403	-0.72V	

Table 7-1. Initial System Balance Records (Sheet 3 of 19)

SITE #5 - Rectifier Output: 25.00V, 6.00A West, 5.00A East
VAB Repeater Building (K6-1193)

Test Location	Readings	Comments
10	-0.98V	New test station at LUT Road
11	-0.98V	Communications cable
	-0.50V	Vent on "Big 3" pipeline, no test leads
15	-0.75V	Comm. cable after bond
	-0.45V	Water line
MH 331	-0.91V	
MH 333	-0.82V	
MH 323	-0.87V	

SITE #6 - Rectifier Output: 13.00V, 12.00A
Corps of Engineering Building (K6-1146)

Test Location	Readings	Comments
MH 403	-0.72V	
MH 413	-0.74V	
MH 401	-1.01V	
Site #6	--	
14	-0.93V	DTA after bond
	-0.60V	Water line after bond
MH 333	-0.82V	
MH 336	-0.82V	
MH 334	-0.93V	

NOTE: Resistance bond was made between communications cable and water line (across bond - 0.65A, 1.00V, 1.6 ohm-centimeters).

Table 7-1. Initial System Balance Records (Sheet 4 of 19)

SITE #7 - Rectifier Output: 50.00V, 10.00A
Tanker Repair Building (K6-1446)

Test Location	Readings	Comments
Site #7	-1.22V	DTA cable
	-0.92V	Tanker Repair Bldg

SITE #8 - Rectifier Output: 18.50V, 4.10A
VAB Instrumentation Building (K7-1557)

Test Location	Readings	Comments
Site #8	--	VAB Inst Bldg
	-0.85V	Fuel Tank
	-0.85V	Elect Ground
MH 426	-1.03V	
MH 421	-0.82V	

SITE #9 - Rectifier Output: 16.00V, 12.50A
Communication Building, Press Site Area

Test Location	Readings	Comments
Site #9	-0.98V	DTA cables
	-0.90V	Elect Ground
	-0.88V	DTA term box at tel trailer
13	-1.04V	DTA cable
13	-1.03V	Comm cabinet 14J23
MH 421	-0.82V	

Table 7-1. Initial System Balance Records (Sheet 5 of 19)

SITE #10 - Rectifier Output: 15.25V, 11.50A East & North, 5.00A West
High Pressure Storage Building (K7-853)

Test Location	Readings	Comments
MH 336	-0.82V	
Turning Basin Cabinet	-0.92V	
MH 418	-0.69V	
MH 338	-0.98V	At Site #10
MH 420	-0.98V	
MH 339	-0.82V	
MH 428	-0.71V	Ord Stor road
MH 342	-0.52V	At DTLR #1

SITE #11 - Rectifier Output: 29.00V, 14.00A
Universal Camera Site No. 18

Test Location	Readings	Comments
Site #11	-1.70V	DTA cable
16	-1.10V	2 DTA cables bonded

NOTE: Solid bond was made between the two DTA cables at Test Station 16.

Table 7-1. Initial System Balance Records (Sheet 6 of 19)

SITE #12 - Rectifier Output: 27.00V, 6.00A South, 6.50A North
Kennedy Parkway at Swartz Road

Test Location	Readings	Comments
MH	-0.87V	
Site #12	--	
17	-0.55V	Water line with bond
	-0.86V	Comm cable in MH with bond
	-0.58V	DTA cable in MH with bond
MH 320	-0.84V	
	-0.97V	100 ft south
	-1.10V	200 ft south (opposite groundbed)
	-1.00V	300 ft south
	-0.84V	100 ft north
	-1.02V	200 ft north (opposite groundbed)
	-0.92V	300 ft north
MH 311	-0.72V	
MH 308	-0.62V	East side insulating joint
	-0.52V	West side insulating joint
19	-0.63V	On DTA only, no test leads to "Big 3" pipeline (Roberts Road)
MH 306	-0.71V	
18	-0.72V	DTA
	-0.90V	Southern Bell cable at crossing
MH 151	-0.99V	DTA cable
	-1.08V	On test station on "Big 3", north side of FCA Road

Table 7-1. Initial System Balance Records (Sheet 7 of 19)

SITE #12 (cont)

Test Location	Readings	Comments
	-0.50V	On vent pipe, "Big 3" pipeline, south side of FCA Road
	-0.71V	Elect ground near Bond #17

NOTE: Water line, DTA cable and duct cables are bonded through a resistance wire in Bond Station #17. Listed below are bond data:

Between duct cable and DTA cable - 0.20A, 1 ohm-centimeter
Between duct cable and Water line - 0.30A, 0.70 ohm-centimeters

SITE #13 - Rectifier Output: 5.00V, 1.20A
Weather Tower No. 6 Equip Building, FCA Road

Test Location	Readings	Comments
MH 151	-0.99V	On DTA cable near manhole
Site #13	-1.17V	DTA cable near MH 156
MH 165	-1.05V	

SITE #14 - Rectifier Output: 4.00V, 2.60A
FCA Site on FCA Road

Test Location	Readings	Comments
MH 165	-1.06V	
MH 171	-0.92V	
MH 175	-0.86V	
Site #14	-0.71V	Electrical ground
MH 177	-0.83V	

Table 7-1. Initial System Balance Records (Sheet 8 of 19)

SITE #16 - Rectifier Output: 8.50V, 14.25A
Unified S Band Operations

Test Location	Readings	Comments
MH 195	-0.67V	SE corner bldg, water line
	-0.67V	4-inch water line to sewer plant
	-0.44V	Fire hydrant south of bldg
MH 194	-0.99V	At rectifier

SITE #17 - Rectifier Output: 5.50V, 8.25A
Visitors Information Center (M6-409)

Test Location	Readings	Comments
MH 193A	-0.96V	
Site #17	01.10V	At Visitors Information Center
MH 187	-0.86V	

SITE #18 - Rectifier Output: 32.00V, 8.00A
CD and SC Building (M6-138), North

Test Location	Readings	Comments
MH 306	-0.71V	
MH 303	-0.74V	
MH 001	-0.99V	
Site #18	-0.83V	Transformer ground, So. Bell Tel Bldg south side
	-1.08V	Conduit, So. Bell Tel Bldg, west side
	-0.85V	Water line, So. Bell Tel Bldg, east side

Table 7-1. Initial System Balance Records (Sheet 9 of 19)

SITE #19 - Rectifier Output: 25.00V, 10.5A
CD and SC Building (M6-138), South

Test Location	Readings	Comments
MH 187	-0.86V	
MH 137	-0.88V	
MH 182	-0.80V	On DTA cable
	-0.44V	Water line near MH 182
MH 004	-0.82V	
At Site #19	-2.60V	Water pipe, air conditioner, S. side CD & SC Bldg
	-0.62V	Fire hydrant, S. side CD & SC Bldg
	-1.30V	Galv. antenna anchor, S. side CD & SC Bldg
	-0.85V	Vault conduit at rectifier
MH 002	-1.04V	
	-0.94V	100 ft south of MH 002
	-1.06V	200 ft south of MH 002
	-1.01V	300 ft south of MH 002 at Causeway
21	-0.89V	On HTHW, no test leads connected to cable
26	-0.81V	On HTHW, no test leads connected to cable

SITE #20 - Rectifier Output: 7.00V, 7.50A
CIF Antenna Site

Test Location	Readings	Comments
MH 127	-0.73V	
MH 131	-0.69V	
MH 136	-0.95V	At manhole
	-0.98V	100 ft south of MH

Table 7-1. Initial System Balance Records (Sheet 10 of 19)

SITE #20 (cont)

Test Location	Readings	Comments
At Site #20	-0. 57V	Water line at air conditioner, W. end of Bldg
	-0. 59V	1. 75-inch water line, W. end of Bldg
	-0. 66V	1. 50-inch conduit, W. end of Bldg
	-0. 61V	Electric transformer ground, S. end of Bldg
	-0. 44V	Fire hydrant, S. end of Bldg

NOTE: This rectifier turned down purposely to allow for polarization. Manholes and duct runs had been pumped out and tests indicated that, as water filled manhole, the reading at MH 136 would be too high.

SITE #21 - Rectifier Output: 10. 00V, 5. 50A
Weather Tower No. 1 Equip Building (TWA Rescue Area)

Test Location	Readings	Comments
Camera Site, UCS #15	-0. 72V	
MH 125	-0. 99V	
Site #21	-1. 75V	DTA cable
MH 122	-1. 07V	

Table 7-1. Initial System Balance Records (Sheet 11 of 19)

SITE #22 - Rectifier Output: 7. 50V, 2. 70A
FCA Van Site

Test Location	Readings	Comments
MH 122	-1. 07V	
Site #22	-2. 20V	On DTA at rectifier
MH 117	-1. 07V	
MH 113	-0. 88V	

SITE #23 - Rectifier Output: 5. 50V, 14. 00A
Banana River Repeater Building (M7-531)

Test Location	Readings	Comments
MH 113	-0. 88V	
MH 108	-0. 92V	
At Site #23	-0. 98V	Electrical ground
	-1. 01V	Building water
MH 1030	-0. 78V	
MH 014	-0. 84V	
MH 010	-0. 82V	

SITE #24 - Rectifier Output: 63. 00V, 6. 00A
NASA Parkway and E. Ave

Test Location	Readings	Comments
MH 007	-0. 83V	
MH 010	-0. 82V	
Hand Hole	-1. 72V	DTA at negative cable connection
	-0. 73V	Abandoned DTA near hand hole

Table 7-1. Initial System Balance Records (Sheet 12 of 19)

SITE #24 (cont)

Test Location	Readings	Comments
MH 034	-0.75V	
MH 146	-0.84V	
	-0.92V	Water valve near MH 146
MH 143	-0.73V	

SITE #25 - Rectifier Output: 3.50V, 2.00A
CIF Building (M6-342)

Test Location	Readings	Comments
MH 007	-0.83V	
MH 004	-0.82V	
MH 137	-0.88V	
26	-0.81V	On HTHW piping only, no leads to cable
25	-0.84V	On HTHW piping only, no leads to cable
MH 126	-0.72V	At MH
	-0.74V	100 ft north of manhole
	-0.92V	150 ft north of MH
	-1.02V	Over cable, opposite groundbed

SITE #26 - Rectifier Output: 23.00V, 6.00A
Electromagnetic Laboratory Building (M6-336)
(Formerly COE Residence Building)

Test Location	Readings	Comments
MH 042	-0.88V	
MH 040	-0.99	Closest to groundbed

Table 7-1. Initial System Balance Records (Sheet 13 of 19)

SITE #26 (cont)

Test Location	Readings	Comments
MH 024	-0.84V	
MH 137	-0.88V	
25	-0.84V	On HTHW pipe, no leads to cable

SITE #27 - Rectifier Output: 6.00V, 1.25A
KSC Headquarters Building (M6-399)

Test Location	Readings	Comments
MH 141A	-1.06V	Closest to groundbed
MH 026	-0.78V	
MH 029	-0.74V	
MH 141	-0.72V	
MH 143	-0.73V	

SITE #28 - Rectifier Output: 15.00V, 5.40A
KSC Auditorium Building (M7-351)

Test Location	Readings	Comments
MH 029	-0.74V	
23	-0.74V	At MH 030 on cables
	-0.46V	At MH 030, on water line, no change
	-0.99V	100 ft west of MH 030, closest to groundbed
MH 034	-0.75V	

Table 7-1. Initial System Balance Records (Sheet 14 of 19)

SITE #29 - Rectifier Output: 14.5V, 9.00A
NASA News Center (M7-657), Industrial Area

Test Location	Readings	Comments
MH 236B	-0.93V	At rectifier
MH 236	-1.04V	DTA at terminal box
MH 237	-0.99V	Closest point to groundbed
MH 034	-0.75V	
At Site #29	-0.55V	Water line, east side of bldg
	-0.68V	Electrical ground, west side of bldg

SITE #30 - Rectifier Output: 47.00V, 6.40A
Gasoline Station at 3rd St and C Ave

Test Location	Readings	Comments
MH 036	-0.85V	With bond
29	-0.85V	Cable
	-0.72	Station water
MH 036A	-1.12	DTA at negative cable connection
28	-0.76	On HTHW, no connection to communications cables
MH 037A	-0.82	
MH 027	-0.77	

NOTE: Resistance bond was made between Station Water System and Communications Cables. Across Bond: 0.37 ohm-centimeters, 0.35A, 0.13V

Table 7-1. Initial System Balance Records (Sheet 15 of 19)

SITE #31 - Rectifier Output: 10.00V, 5.25A South, 0.75A North
KSC Main Cafeteria (M6-493)

Test Location	Readings	Comments
MH 024	-0.82V	
MH 025	-0.84V	
MH 026	-0.78V	
24	-1.08V	Comm. cable only, no other leads
	-0.52V	HTHW at groundbed (north)
	-0.67V	Water line at groundbed, no change
	-0.45V	Fire hydrant at groundbed, no change
	-0.85V	Water line to air conditioner, S. side bldg near groundbed (south)

SITE #32 - Rectifier Output: 3.50V, 0.80A
Paint and Oil Storage Building (M6-584)

Test Location	Readings	Comments
MH 042	-0.88V	
MH 049	-0.95V	
MH 047B	-0.86V	
27	-0.92V	Cable only, leads to HTHW not connected
MH 046	-1.03V	At negative cable connection
HTHW	-0.83V	Across road from goundbed

Table 7-1. Initial System Balance Records (Sheet 16 of 19)

SITE #33 - Rectifier Output: 17.00V, 5.75A
Kennedy Parkway and 5th Street

Test Location	Readings	Comments
MH 049	-0.95V	
MH 060	-0.99V	At rectifier
	-0.39V	Fire hydrant - no change
	-0.84V	Terminal cabinet, guard house (DTA Cable)
MH 065	-0.93V	At Ransom Road

SITE #34 - Rectifier Output: 8.00V, 2.50A
Automotive Maintenance and Services (GSA Motor Pool)

Test Location	Readings	Comments
MH 049	-0.95V	
MH 059	-0.76V	
MH 053	-1.08V	At negative cable connection
Site #34	-0.72V	GSA water
	-0.74V	GSA electrical ground

SITE #35 - Rectifier Output: 2.50V, 1.20A
Radar Boresite Building (M7-867)

Test Location	Readings	Comments
MH 239	-0.73V	
MH 245	-0.68V	On DTA at manhole
MH 241C	-1.04V	No water in manholes
At Site #35	-0.82V	Water at building
	-0.82V	Electrical ground

Table 7-1. Initial System Balance Records (Sheet 17 of 19)

SITE #36 - Rectifier Output: 6.00V, 9.25A
Ordnance Laboratory (M7-1417)

Test Location	Readings	Comments
MH 245	-0.68V	On DTA at MH
MH 252	-0.74V	
MH 250	-0.78V	
30	-0.64V	On HTHW only, no leads to cables
Site #36	-0.92V	At rectifier
	-1.06V	100 ft south of building
	-0.79V	Electrical ground
	-0.82V	Building water

SITE #37 - Rectifier Output: 32.00V, 8.00A
Former FEC Communications Area

Test Location	Readings	Comments
MH 065	-0.93V	At Ransom Rd Insul joint, Duct Cables
	-0.91V	At Ransom Rd Insul joint, DTA North
	-0.59V	At Ransom Rd Insul joint, DTA South (not protected)
	-0.74V	On Ransom Rd on Big 3 pipeline - no change
	-0.56V	DTA-Ransom Rd at "Big 3" pipeline (not protected)
Site #37	-0.99V	At S. End Bldg, Site #37
	-0.96V	At MH 069, closest to groundbed
	-0.88V	At MH 069 over DTA, no bond required
	-0.41V	Water line at DTA crossing, no change
MH 077	-0.85V	

Table 7-1. Initial System Balance Records (Sheet 18 of 19)

SITE #38 - Rectifier Output: 23.00V, 4.50A
South Repeater Building (N6-1118)

Test Location	Readings	Comments
MH 077	-0.85V	
MH 081	-0.99V	At manhole
	-0.98V	At MH, 100 ft south
	-0.74V	Electrical ground, at building
	-0.69V	Building water
MH 085	-0.98V	

SITE #39 - Rectifier Output: 59.00V, 2.60A
Weather Tower No. 5 Equipment Building

Test Location	Readings	Comments
MH 085	-0.98V	
MH 092	-0.99V	At Site #39
MH 098	-0.94V	

SITE #40 - Rectifier Output: 4.00V, 12.50A
Tel IV Building

Test Location	Readings	Comments
MH 098	-0.94V	
69, Camera Site, UCS #1, DTA	-1.00V	
MH 100	-0.87V	At MH
	-0.97V	At MH, 50 ft south

Table 7-1. Initial System Balance Records (Sheet 19 of 19)

SITE #40 (cont)

Test Location	Readings	Comments
	-0.62V	HV reclosure #13
	-0.64V	Anchor, weather tower
	-0.51V	Hooked to instrumentation ground, N. side
	-0.70V	Piping at air conditioning
MH 101	-0.74V	At MH (shielded area)
34	--	Test station at insul joints
	-0.84V	N. side of insul joints
	-0.52V	S. side of insul joints

SECTION VIII
REPAIR AND REPLACEMENT PROCEDURES

8.1 GENERAL

This section contains repair instructions for the Cathodic Protection System to include the method of attaching rectifier leads and test leads to communication leads and to pipes.

8.2 SAFETY PRECAUTION

For appropriate safety precautions, refer to Paragraph 5.2.

8.3 CONNECTION TO COMMUNICATION CABLE

Make connections to the communication cables as described under Bonding of Tape Armored Cables as described in T.O. 31W3-10-13, except that the test lead will be used instead of a bonding ribbon.

8.4 CONNECTION TO PIPES

Make connections to underground pipes by Cadweld connections. The connection is then protected by coating with bitumastic or hot applies tape extending at least two inches on each side of the connection.

Section IX, Parts and Component Assemblies, deleted.

SECTION IX
VENDOR DATA

Refer to the Instruction Manual for PEM Quality Rectifier for replacement parts information.